HISTORY

OF THE

PROGRESS

AND

PRESENT STATE

OF

ANIMAL CHEMISTRY.

BY

W. B. JOHNSON, M. B.

IN THREE VOLUMES.

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TABLE OF CONTENTS

OF THE

THIRD VOLUME.

VOL. III.

ERRATA.

Page 12, l. 14, *for* every *r.* very—P. 24, l. 2, *for* gaſtric *r.* galvanic—Page 155 is marked by miſtake 115—Page 197, line 10 from bot. *for* indigeſtion *r.* ingeſtion—P. 207, l. 29, *for* acid *r.* aid—Page 229, l. 17, *for* on the contrary, *r.* if, on the contrary—P. 235, l. 10, *for* matter of *r.* matter, of—ib. l. 28, *for* weight *r.* in weight—P. 236, l. 13, *dele* and—P. 239, l. 16, *for* A certain *r.* 1. A certain—P. 267, l. 27, *for* thus *r.* this—P. 275, line 2 from bot. *for* Daniel *r.* David—P. 279, l. 15, laſt century *add* but one.

THE

HISTORY

OF

ANIMAL CHEMISTRY.

LIFE.

The Vital Principle.

THAT life is a material principle, and consequently ſubject to the laws of chemical affinities, has been aſſerted by ſeveral philoſophers; but although no ſatisfactory explanation has yet been given reſpecting it's action, or mode of producing it's various effects, when conſidered in a chemical view, it will not be deviating from the object of the preſent work to give a few of the principal opinions that have been held of it's nature.

The exiſtence of a living principle in the animal body has been acknowledged from the earlieſt ages. At firſt it was looked upon as being particularly connected with the blood; for, having obſerved that the body was deprived of life by great evacuations of blood, either in battle or by accidental cauſes, it was natural to conclude that this fluid conveyed the living principle out of the wound, and pro-

Mofes. duced death. This was the idea of Mofes, and the reafon why that legiflator prohibited the Ifraelites from eating blood. "Therefore I faid unto the children of Ifrael, Ye fhall eat the blood of no manner of flefh; for the life of all flefh is the blood thereof. I will even fet my face againft that foul that eateth blood; for the life of the flefh is in the blood." Homer gives death the epithet purple, πορφυρεος θανατος: and Virgil alludes to it when Empedocles. he fays, *purpuream vomit ille animam.* Empedocles and Critias believed life to be the blood itfelf.

Upon examining the opinions of the ancient fects of philofophers, on the immateriality and materiality of the foul, it would appear, that the immaterialifts, confidering all the fubtile and invifible fluids as not fubject to the laws of matter, thought they had difcovered amongft them the origin of the foul, whilft fome of them feem to have con-Heraclitus. founded the foul with the living principle. Thus Heraclitus looked upon the foul, or intelligent principle, as incorporeal, or an exhalation; Parmenides, that it was fire; Parmenides. Epithormus, that it was extracted from the fun; and Anaxagoras, Anaximenes, and Archelaus, that is was a fub-Hippo. tile air. Hippo afferted it to be a vapour; for, according to him, humidity was the principle of all things; and Boëcius, Antoninus. that it was compofed of air and fire. Marcus Antoninus the Stoic was perfuaded of it's great refemblance to the wind, and Critolaus imagined that its effence was a fifth fubftance. Many of the moderns have fuppofed the foul originates from the feminal liquor; that at firft it is merely a vegetating principle, like unto that of a plant, but afterward, on becoming more perfect, it acquires a fenfitive property, and is at laft rendered reafonable by the divine cooperation.

Pythagoras. Pythagoras had imagined the foul to be detached from the air, and had invented an *anima mundi*, from

which the fouls of men were emanations: but as the reciprocal action of the foul and the body upon each other was not eafily explained on the fuppofition of immateriality, Plato feems to have improved on the idea of Pythagoras, by propofing that of a *plaftic nature*, a kind of intermediary living principle connecting the foul and body; and this plaftic principle was acknowledged even by Hippocrates and Ariftotle, although differently modified by various fects. Ariftotle the peripatetic, and the fcholar of Plato, afferts the foul to be the firft entelechia of the natural organic body, having the living principle under it's direction. It has three faculties; the nutritive, the fenfitive, and the rational. The firft is that in which life is the only acting principle. The fecond is that by which feeling is produced. The third is peculiar to man, and is that part of him which knows and judges. This intellect is either an intellectum agens vel patiens. The firft may be feparated from the body, and is immortal: the other is perifhable. Life is a permanence of the foul, according to this philofopher, retained by the natural heat, and the principle of this heat is in the heart. Galen was much attached to the doctrine of Ariftotle, and made commentaries full of erudition on the works of that philofopher. Among the Arabs, Avicenna and Averroes were the principal who commented on the doctrine of the Stagyrite. Among the phyficians of Italy that followed the fame doctrine was Andrew Cefalpinus, firft phyfician to Clement VIII; and it ended with Corringius.

Plato.

Ariftotle.

Galen.

Leucippus, Democritus, and Epicurus were real materialifts. They were of opinion there was nothing in exiftence but body, and that the principle of life and intelligence are only modifications of matter; that they arife from the difpofition of the atoms in organized bodies, in the fame manner as the flefh, the blood, and other fenfible parts.

Epicurus.

Lactantius, who believed the ſoul likewiſe corporeal, after having examined all the various opinions of philoſophers on the ſubject of the eſſence of which the ſoul is compoſed, and having regarded them all as uncertain, acknowledges, however, they are not without ſome ſhare of truth—our ſoul, or the principle of life, being in the blood, in the heart, and in the ſpirit—but that it is impoſſible to expreſs the nature which is the reſult, being more eaſy to ſee the operations of it than to define it.

It would appear, therefore, all the ancients had ſome idea of a living principle which animates the corporeal Plutarch. machine; and this is aſſerted by Plutarch, who ought to know beſt the ſentiments of the ancients, having given a treatiſe on their opinions. He ſays, as being acknowledged by all of them, that ſpirit is only a ſubtile matter, and our ſoul, which is the air, keeps us alive; and in this manner all the world contains ſpirit and air, which are only two names ſignifying the ſame thing.

The anima mundi of Pythagoras, the φυσις of Hippocrates, and the πνευμα of the author of De Mundo, was afterwards deſcribed by the name of *calidum innatum*, as expreſſing the vital principle: and ſome of the firſt reſtorers of letters adopted the ſame opinion: and during a conſiderable part of the ſeventeenth century, a regular ſyſtem prevailed, by which the vital principle was reckoned the efficient cauſe of generation and exiſtence in all animals and plants. It then took the name of *anima vegetans*.
Paracelſus. Paracelſus changed this term, in his hypothetical and fanciful method of reaſoning, for that of *ſidereal ſpirit*, which, according to his opinion, was equally independent of the body and the mind, but deſcended from the firmament, as the rational ſoul proceeded from the deity. Van Helmont, who thought he improved upon the ſyſtem of his maſter Paracelſus, ſuggeſted the theory of the Archeüs, without venturing to aſſert the unity of the rational and

living souls. The actions of the Archeüs were afterwards reduced by Stahl to the operations of the *rational soul*; but, according to Dr. Ferriar, Descartes appears to have been the first modern philosopher who rejected the separate existence of the vital principle, under all denominations. He availed himself of the progress that was made in the nervous physiology not long before, by Willis and others, to form an hypothesis of the vital functions, founded on the supposition of the nervous fluid or animal spirits, which was the language of that period. The doctrine of Stahl made considerable progress; and the supposition of a rational power, or vis medicatrix naturæ, which directs all the actions of the body both in health and disease, became universal; and for a long time the terms of nature, sensitive soul, and vital principle, were employed without much opposition. The existence of a nervous fluid was now assumed independently of the sensitive soul, to explain the appearances of sensation and voluntary motion. Stahl.

About the middle of the last century, when Haller was asserting his theory of the *vis insita*, and *vis nervea*, Dr. Whytt of Edinburgh attempted a reformation of the Stahlian doctrine, which excluded the independent living principle. He supposes the soul to be present in different parts of the brain at the same time, while he considers this soul as immaterial and unextended. Whytt.

Some philosophers at length began to imagine that matter might acquire vitality, in consequence of a certain organization, and amongst these were Buffon and Hoffmann. But while no single hypothesis respecting the vital principle prevailed generally, two theories appeared, which more particularly engaged the attention. Dr. Monro gives his explanation of the *intellectus agens* in the body, by saying, that the power which created all things, which gave life to animals, continues to act upon and to maintain all, Buffon. Monro.

by the unceafing influence of a living principle pervading the univerfe, the nature of which our faculties are incapable of duly comprehending. The other theory was that of John Hunter, who revived the idea of the blood being endued with the living principle. This opinion, as obferved before, is not only to be found in the writings attributed to Mofes, but in modern times it had been afferted by Harvey, Hoffmann, and more particularly by Huxham, who even mentions the red globules as the peculiar feat of life. The proofs which John Hunter brings of the life of the blood are the following: 1. It unites living parts when effufed between them. 2. The blood becomes vafcular, like other living parts. 3. It's temperature, as it flows from the vein, is always equal, in the moft oppofite temperatures to which the body can bear expofure. 4. It is capable of being acted upon by a ftimulus, as is the cafe when it coagulates. 5. The laft direct proof of the life of the blood is the nourifhment and prefervation of life in paralytic limbs.

Hunter.

Goodwyn.

Goodwyn, who endeavoured to confider the fubject of vitality in a manner different from what it had been, taking the living body when all the accidental figns of life are removed, and applying to it thofe external powers which really do reftore them, then attending to the place and circumftances of their firft operation, and the immediate effects they produce, was led to examine the effential quality of life, and confequently to the means of diftinguifhing it from death. This phyfician is of opinion, that the heart is the great feat of the principle of life, in all the more perfect animals; and that the contraction of the heart with the ordinary ftimulus is the only mark of the prefence of this principle; that when the heart contracts, under fuch circumftances, the body is alive; when not, it is dead. Life he therefore defines to be the faculty of propelling the fluids through the circulatory fyftem. Ac-

cording to him, the external concomitant circumſtances which operate upon the body in health are heat and reſpiration, which excite the vital principle to action; and whenever the functions of an animal are ſuddenly ſuſpended, and the body puts on the appearance of death, it is always in our power to determine whether it be really dead, by reſtoring the temperature, and by inflating the lungs with proper air. He is of opinion, with ſome others, that there are no means of determining the abſolute deprivation of the vital principle but by the preſence of putrefaction.

Currie, on appreciating the powers of life, affirms, that if a definition of it were required, it might be moſt clearly eſtabliſhed on that capacity by which the animal preſerves it's proper heat under the various degrees of temperature of the medium in which it exiſts. That the more perfect animals poſſeſs this power in a ſuperior degree: and this is neceſſary from the exerciſe of their vital functions. That the inferior animals have it in a lower degree, and vegetables lower ſtill; which is according to their limited powers and humbler organization. And as the capacity of preſerving nearly an uniform temperature in all varieties of climate and ſeaſon is a criterion of life in the more powerful animals, it is probable that a few degrees of increaſe or diminution of the heat of the ſyſtem produce diſeaſes and death. Metzler ſuppoſes carbonic acid gas to afford the principle of life. De la Metherie looks upon the principle of life to be the aura animalis, ſomewhat analogous to the aura ſeminalis; and Girtanner affirms irritability to be the principle of life. Somewhat before the time when Goodwyn publiſhed his "Connection of Life with Reſpiration," a revolution had taken place in chemiſtry, and the attention of philoſophers became more particularly directed to inveſtigate the chemical proceſſes that were ſuppoſed to take place in the animal economy, and by which the principle of life came in for it's ſhare. This change

Currie.

De la Metherie.

in the ſyſtems aroſe from the diſcovery of oxygen, which was found to be that principle which ſome of the ancients had imagined to exiſt in the atmoſphere—a certain ſomething which they ſaw was neceſſary to life. This oxygen is the pneuma that Ariſtotle ſays unites with the blood; and Chryſippus von Soli, who gave to the pneuma the moſt extenſive range, expreſsly declares that it is what generates life; whilſt Praxagoras the phyſician ſays that the ſoul is ſtrengthened by ſpirituous air.

This theory of Chryſippus and Praxagoras had it's diſciples in the middle ages, and in latter times it received great influence from the diſcovery of the circulation of the blood. For this diſcovery we are indebted to Michael Servetus or Andrew Cæſalpinus, each having mentioned that circumſtance before Harvey. It now became clear where the blood met with the inſpired air, and how it was then ſent through the body. Servetus expreſsly ſays that the blood paſſes through the lungs, obtains there an addition of vital ſpirit from the atmoſpheric air, and returns

Bacon. impregnated with this from the lungs to the heart. Bacon added to the doctrine of the pneuma, and ſays the vital ſpirit is compoſed of air and fire, which by their union produce a weak combuſtion, or, as it may be called, the *phlogiſtic* proceſs of life *(incenſio ſpirituum vitalium)*. Hence, from the time of Praxagoras there appears to have been a ſimilar idea of a *material principle* of life, although differently modified; and this appears to have been the opinion likewiſe of Harvey, Mayow, and Mund, and to have

Townſend. deſcended to the preſent times. Thus Townſend affirms, the vital force of an organ appears to be in the exact proportion of the quantity of oxygenated blood that circu-

Thornton. lates through it; Thornton, that there is a chemical proceſs going forward in the body by means of oxygen; and

Brandis. Brandis, Reil, and Gallini are of the ſame opinion, but ſay the vital power ariſes from a conſtant change of animal

matter, a phlogiftic procefs, which is maintained and renewed by an union of the oxygen with the carbon. According to Hufeland, life is a chemico-animal flame, to the production of which oxygen is abfolutely neceffary, and the vital power is the moft general and powerful of all the powers of nature. He confiders it as the caufe of organization, and as poffeffing the following properties. 1. It has a greater affinity to fome organized bodies than to others; thus, the polypus may be cut in pieces without being divefted of it, and a decapitated tortoife or a frog deprived of it's heart will live a long time after; whilft to the human body, or a quadruped, it would be inftant death. According to this phyfiologift, it appears to be a general rule, that the ftronger the affinity is between life and an organized being, the more imperfect is the animal: hence the zoophytes, whofe whole organization confifts in a mouth, a ftomach, and a gut, have a life exceedingly tenacious, and difficult to be deftroyed. 2. It is in greater quantity in fome organized bodies than in others. Thus an elephant lives a century, whilft the ephemeron only exifts a day; and in general all cold-blooded animals live longer than thofe with warm blood. 3. It frees bodies from the chemical laws of inanimate matter, and transfers the component parts of a body from the phyfical or chemical to the organic or living world. 4. It prevents putrefaction, for no organized body can putrefy unlefs deprived of life. *Hufeland.*

Humboldt is of opinion, that the degree of vitality depends upon the reciprocal balance of the chemical affinities of all the elementary parts of which an animal is compofed. Humboldt.

Davy confiders life as a perpetual feries of peculiar corpufcular changes, and the living body as the being in which thefe changes take place. They are confequently found to be continually varying: and fince all organic fen- Davy.

ſitive beings are unable to exiſt without light and oxygen, he looks upon theſe two, under the name of phoſoxygen, as eſſential to exiſtence.

Dr. Ferriar oppoſes the living principle.

Dr. Ferriar, in his obſervations concerning the vital principle, thinks that ſome direct arguments may be brought againſt the general ſuppoſition of an independent living principle. Theſe arguments he divides into two kinds, viz. refutations of the general proofs offered in ſupport of the vital principle; and inſtances of the direct influence of the mind and brain over what is termed the independent living principle. The great proofs for the ſupport of a vital principle are, the contraction of muſcles ſeparated from the body on the application of ſtimulants; the performance of the vital and involuntary motions without any exertion or even conſciouſneſs of the mind, and the birth of full-grown fœtuſes deſtitute of a brain. In all theſe caſes, ſomething is alleged to operate, independently of the mind, in producing muſcular motion.

Dr. Ferriar, in anſwer to the firſt argument drawn from the contraction of ſeparated muſcles, affirms, it may be ſaid, 1. That the power of contraction in a ſeparated muſcle is loſt before putrefaction takes place, *i. e.* before the deſtruction of it's texture; but if it's vitality depended on it's texture this ought not to happen. 2. The power of contraction in a ſeparated muſcle is ſtrongeſt upon it's firſt ſeparation, and becomes weaker by degrees: therefore the contracting power appears to have been derived from ſome ſource from which it is detached by the exciſion of the part. 3. Irritation of the medulla oblongata, or of the nerves ſupplying particular muſcles, occaſions ſtronger contractions than irritation of the muſcles themſelves; and Dr. Whytt furniſhes an experiment on a frog, directly proving that the action of ſeparated muſcles depends upon the nervous energy. 4. Dr. Haller himſelf is obliged to make a conceſſion on this ſubject ſufficient to

deſtroy his favourite hypotheſis of the vis inſita. 5. When a paralytic limb is convulſed by the electric ſhock, the motion never takes place without the patient's conſciouſneſs. In this caſe there is no diſtinction between the vital principle and that exertion which in voluntary motion is always attributed to the mind.

In anſwer to the ſecond argument in favour of a vital principle, drawn from the performance of the vital and other involuntary motions, Dr. Ferriar contents himſelf with only obſerving, that allowing the organs of thoſe motions to be ſupplied with nervous energy, their motions may be very well accounted for by the ſtimulus of their contained fluids.

The force of the third argument, drawn from the want of a brain in full-grown fœtuſes, is taken off by Dr. Whytt, who remarks, that as the heart is ſometimes wanting in full-grown fetuſes, the argument would equally prove that the heart is not neceſſary for the continuance of circulation, as that the brain is not neceſſary to the ſupport of the ſyſtem. Accordingly, fetuſes born without a brain do not in general ſurvive birth.

Beſides the general ſuppoſition of an independent living principle, an inference has been drawn from facts, of a nervous energy independent of the brain. By this term is meant, that condition derived from the brain to different parts of the body, by means of which they become capable of motion. To ſhow by direct proof that there is no independent vital principle, Dr. Ferriar obſerves, 1. That it is juſtly urged by Dr. Monro againſt the doctrine of the vis inſita, that there is too much deſign in the actions of different muſcles, affected by different ſtimuli, to be the effect of mere mechaniſm. Thus, when the hand or foot is burnt, or otherwiſe ſuddenly injured, the muſcles on the part immediately ſtimulated are not thrown into action, nor the muſcles on the ſide irritated, but their

antagonifts contract immediately and ftrongly. Now, if the inftantaneous action be in this cafe chiefly produced by an effort of the mind, the fuppofition of a diftinct vital principle is fuperfluous: if it be faid to be produced by a living power independent of the mind, then there muft be a rational power in the body, independent of the mind; which is abfurd. 2. The ftate of the vital and involuntary motions is confiderably affected by the ftate of the mind, which equally difproves the exiftence of a feparate vital principle, and proves the dependence of the nervous energy upon the brain. 3. Madnefs, it is well known, is frequently produced by caufes purely mental, and in perfons apparently in good health; and as the patient's fenfibility to very powerful ftimuli is much diminifhed in maniacal cafes, they afford another proof of the fubordination of the nervous energy. 4. It has been obferved, that in paralytic cafes motion is frequently deftroyed, while fenfe remains. As the caufe of palfy almoft always refides in the brain, this fact appears equally inexplicable on the opinion of a diftinct living principle, or of a nervous energy independent of the brain. 5. When nerves are regenerated after being cut through, fenfation and voluntary motion are not always reftored to the parts beneath the divifion: the reftoration was never made in Dr. Monro's experiments. But on the fuppofition of a diftinct nervous power, the nerve, after it's reunion, ought to refume all it's offices. 6. Dr. Whytt afferts, that when the fpinal marrow of a frog is deftroyed, after decollation, no contraction can be excited in the limbs by cutting or tearing the mufcles. Such are the facts and arguments which Dr. Ferriar brings againft the opinion of a diftinct living principle; and he thinks that their inveftigation appears to lead us back to the brain as the fource of fenfibility and irritability.

Dr. Rufh. The laft opinion which has been given of the principle

of life is that of Dr. Rufh. He includes in animal life three properties, as applied to the human body; viz. *motion*, *fenfation*, and *thought*, and thefe, when united, compofe perfect life. It may exift without thought or fenfation, but neither fenfation nor thought can exift without motion. He affirms, that the loweft degree of life exifts in the abfence even of motion. He firft confiders animal life as it appears in the waking and fleeping ftates in a healthy adult, and afterwards inquires into the modification of it's caufes, in the fœtal infant, youthful and middle ftates of life, in certain difeafes, in different ftates of fociety and in different animals, and lays down the following propofitions:

1. Every part of the human body, the nails and hair excepted, is endued with fenfibility or excitability, or with both.

2. The whole body is fo formed and connected, that impreffions made in the healthy ftate upon one part excite motion or fenfation, or both, in every other part of the body.

3. Life is the *effect* of certain ftimuli acting upon the fenfibility and excitability, which are extended in different degrees to every external and internal part of the body; and thefe ftimuli are as neceffary to it's exiftence as air is to flame.

That animal life is a forced ftate was firft delivered by Dr. Cullen, although he afterwards retracted it. He affirmed that the human body was not an automaton or felf-moving machine, but kept alive, and in motion, by the conftant action of ftimuli upon it. Dr. Brown enlarged upon this, and formed a beautiful theory of excitability and excitement: and Dr. Rufh endeavours to eftablifh this difcovery of life being a forced ftate; and he continues to obferve, that the action of the brain, the diaftole and fyftole of the heart, the pulfation of the arteries,

the contraction of the mufcles, the periftaltic motion of the bowels, the abforbing power of the lymphatics, fecretion, excretion, hearing, feeing, fmelling, tafte, and the fenfe of touch, even *thought* itfelf, are all the effects of ftimuli acting upon the organs of fenfe and motion. Thefe have been divided into external and internal.

1. The external are light, found, odours, air, heat, exercife, and the pleafures of the fenfes.

2. The internal ftimuli are food, drinks, chyle, blood, tenfion of the glands which contain fecreted liquors, and the exercife of the faculties of the mind.

Life therefore (according to the hypothefis of Rufh), even thought itfelf, is merely a quality refiding in the component parts of a material fyftem, dependent upon a peculiar organization, by which it is enabled to act, or in fome way to move, on being ftimulated or excited. Hence life can never be inherent in a fimple uncompounded fubftance, nor in a particle of animal matter; and if the ftimulus be withheld from a living fyftem beyond a given time, all motion, fenfation, and thought, muft neceffarily be extinguifhed.

He then inquires into the ftate of animal life in fleep, in the fœtus, in infants, in youth and middle life, in old age, in perfons who are blind, deaf and dumb, in idiots, in thofe under the effects of long fafting, and in thofe fuppofed to be dead, from drowning, freezing, and other caufes. He afterwards takes a view of the ftate of animal life among the different inhabitants of the globe, as varied by civilization, diet, fituation, and climate. He accounts for the influence of certain mental ftimuli, which act nearly alike upon the individuals of all nations; of the caufes of life in all the different claffes of animals; of the caufes of life in vegetables; of the caufes of death; and laftly, he draws his conclufions from the doctrine of animal life being the effect of impreffions upon the body.

Irritability.—Whatever motion there is in the animal body, it is all brought about by the muſcular fibre; and ſince the connection of this fibre with oxygen is neceſſary, in order that it ſhall preſerve it's irritable or contracting power, phyſiologiſts have endeavoured to inveſtigate what may be the nature and origin of irritability itſelf.

Gliſſon is ſaid to be the firſt diſcoverer of the irritable principle in the ſolid fibre, and this was afterwards enlarged upon by Haller, who found by a variety of experiments that the irritability of muſcles remains a long time after their connection with the brain is deſtroyed. He gave it the name of vis inſita. Fothergill, in his Hints on Animation, publiſhed in 1783, conſiders oxygen as the proximate cauſe of irritability; and Girtanner looks upon himſelf to be the diſcoverer of the ſame principle in the fluids of the body; and it is to this celebrated phyſiologiſt, and to Humboldt, that we are indebted for the moſt curious obſervations on this principle.

According to Girtanner, who has made a number of experiments on the ſubject, irritability is the principle of life in organized nature, and oxygen is the principle of irritability. His opinion is, that the irritable fibre, improperly called the muſcular fibre, is univerſally expanded throughout all organized nature. It is on this that organic motion, ſenſation, and even life depends. He affirms that this irritable fibre is the ſame in all parts, and ſubject to the ſame laws; that the fluids of animals are endued with irritability as well as the ſolids, their irritability conſiſting in their coagulability, which is ſubject to the ſame laws as that of the fibre; that the degree of irritability of the ſolids and fluids is continually changing, and is different, according to the age and regimen of the ſame animal, according to the ſex, organization, and ſize of the individual; that the ſtate of health, or the tone of the fibre, conſiſts in a certain quantity of the irritable Girtanner.

principle neceſſary to it's preſervation. To maintain this ſtate, it is neceſſary the action of the ſtimulus be ſufficiently ſtrong to deprive the fibre of the ſurplus of the irritable principle which the lungs and the circulation of the fluids continually furniſh. When the irritability is totally deſtroyed, the fibre is in a ſtate of gangrene; it changes it's colour, becomes livid or black, and is then ſubject to the laws of unorganized matter. That the irritable fibre, from the firſt moment of it's exiſtence to that of it's diſſolution, being conſtantly ſurrounded by bodies that act on it by ſtimulating it, and upon which it reacts by it's contraction, it follows, that during life the irritable fibre is in a continual action; that life conſiſts in action, and is not a paſſive ſtate, as ſome authors have advanced. According to the experiments of this phyſician, poiſons act on the blood, as was before obſerved by Fontana, by depriving it of the principle of irritability, or of it's oxygen.

He then attempts to prove that it is to the oxygen, diſtributed to all parts of the ſyſtem by means of the circulation of the blood, that the irritability and the life of organized bodies are owing. The proofs of which are,

1. The irritability of organized bodies is always in a direct ratio to the quantity of oxygen they contain.

2. Every thing that augments the quantity of oxygen in organized bodies augments at the ſame time their irritability.

3. Every thing that diminiſhes the quantity of oxygen diminiſhes likewiſe their irritability.

He diſtinguiſhes the organized fibre by three different ſtates:

1. A ſtate of health, or the *tone* of the fibre, in which the oxygen exiſts in it's proper quantity.

2. A ſtate of *accumulation*, in which the fibre is ſurcharged with the oxygen or irritable principle.

3. A ſtate of *exhauſtion*, in which the fibre is more or leſs deprived of it.

He likewife arranges all fubftances, that are capable of coming into contact with the irritable fibre, into three claffes.

The firft comprehends thofe fubftances that have the fame degree of affinity for the irritable principle or oxygen, as the organized fibre itfelf; hence the fubftances produce no effect upon it.

The fecond comprehends thofe fubftances that have a lefs degree of affinity for oxygen than the organized fibre has: hence thefe, when they come into contact with it, furcharge it with oxygen, and produce a ftate of *accumulation*. They are called negative ftimuli.

The third comprehends fubftances for which oxygen has a greater affinity than it has for the organized fibre. Thefe therefore deprive the fibre of it's oxygen, and produce a ftate of *exhauftion*. They are called pofitive ftimuli.

It is a fact well known, that the affinity of different fubftances differs confiderably, according to the degree of temperature. The fame difference, according to this phyfician, takes place with the organized fibre; hence, in fpeaking of the affinities of the irritable fibre in general, he means the temperature to be that of the blood in warm-blooded animals. Having made this obfervation, his arrangement of different fubftances is as follows:

In the firft clafs he arranges all organized or living fubftances, which produce no effect upon the irritable fibre as long as their degree of temperature is the fame as that of the fibre with which they come into contact.

In the fecond clafs (negative ftimuli) he arranges fome of the moft fatal poifons. And it is on this account that the oxygenated muriatic acid is fo deadly a poifon to all organized bodies. It deftroys them by the furcharge of irritability, or by fuperoxygenating them; and the confequence is, it is changed into common muriatic acid. Arfenic in it's metallic ftate has no effect; but the white oxyd

of this metal is one of the moſt excruciating and terrible poiſons. The oxygenated metallic ſalts, as corroſive ſublimate, or oxygenated muriat of mercury and butter of antimony, produce the ſame effects. Alſo the oxyds of ſilver and mercury produce more or leſs effects on the organized fibre, according to the quantity of oxygen they contain. The black oxyd of mercury, or Æthiops mineral, produces little or no action; whilſt the red oxyd of the ſame metal produces the moſt terrible effects, and deſtroys organized bodies in a very ſhort time. The action of the ſulphats of tin and lead, and the acetates of lead and copper, is the ſame on the organized fibre.

He aſſerts that the animal as well as the vegetable organized fibre decompoſes the water with which it comes into contact; that the greateſt part of the water we drink is decompoſed, then recompoſed; that it is another method which nature makes uſe of to furniſh organized bodies with the oxygen neceſſary to preſerve their life and irritability. Hunger he looks upon as the conſequence of accumulated irritability in the ſyſtem; and for a ſubſtance to be nouriſhing, it is neceſſary for it to be a poſitive ſtimulus, *i. e.* it muſt have a great affinity for the oxygen with which the ſyſtem is overloaded, by which it gives tone to the fibre, and ſtops the diſagreeable ſenſation of hunger. Different ſubſtances, therefore, are only nouriſhing in proportion to their affinity for oxygen. It is on this account that living animal ſubſtances, as oyſters, afford little or no nouriſhment, becauſe, being already ſaturated with oxygen, they cannot combine with it; and hence the well-known obſervation, that oyſters increaſe the appetite. Likewiſe animal jellies, fruits and vegetables, in general, nouriſh very little, or not at all. The fleſh of newly-killed animals is not ſo nouriſhing as that kept for ſome time, and when raw is leſs ſo than roaſted. From this ariſes all the art of the cook, which only conſiſts in de-

priving the flesh of it's oxygen by different stimulating substances, such as heat, oils, sugar, alcohol, and other substances that have a great affinity to oxygen, and are very nourishing. In the East-Indies, millions nourish themselves by eating small quantities of opium when their crops of rice fail.

Thirst is a state of the system opposite to that of hunger; it is a sensation that indicates an exhaustion or want of oxygen. Water therefore, on being decomposed, as it comes into contact with the fibre, gives up it's oxygen to stop this disagreeable sensation. The same happens with vegetable acids, which are always decomposed in the stomachs of animals. If these acids are the best remedies against the effects of narcotic poisons, it is owing to their giving up the oxygen, on decomposition, to the fibre which these poisons have deprived of it. Hence vinegar cures the effects of opium and drunkenness, which is likewise effected by a large quantity of water. The freshness of the air after rain arises from the aqueous vapours coming into contact with our bodies, and restoring to them their lost oxygen. That singular insect the rotifer may be revived, after having been perfectly dried, by moistening it with water, which, on being decomposed, restores to it it's oxygen, and consequently it's irritability, of which the stimulus of heat had deprived it.

In the third class (positive stimuli) he arranges alcohol, sulphuric æther, opium, and other narcotics; oil of laurel, and oils in general; fat, sugar, &c. All the substances are combustible; *i. e.* they have a great affinity to oxygen; and it is by the same property they deprive the organized fibre of it's irritability, by uniting with the oxygen they contain. Amongst the positive stimuli that produce the most terrible effects are those of the putrid fever or plague, and of mephitic gas, which exhales from putrid animal

ſubſtances where the common air is not able to penetrate, as in tombs. The affinity of mephitic gas for oxygen is ſo great, that as ſoon as it comes into contact with the organized fibre it deprives it of all it's oxygen, and produces death, which is ſometimes immediately. The beſt way therefore to prevent the effects of this gas, is to detonate nitre on burning coals. The oxygen of the nitre combines with the gas, and renders it inert; and hence the uſe of reſpiring oxygen gas by thoſe who are ſuffocated by it, and the freſhneſs, as they expreſs, which it affords.

Humboldt. Humboldt, who has written an ingenious treatiſe on the nature and properties of the Galvanic fluid, looks upon irritability to be the common foundation of all vital action; and that it depends upon the property of the elementary parts of the muſcular fibre to change their relative ſituation on the approach of a ſtronger or weaker ſtimulus, whilſt in the ſenſible fibre of the nerve a fluid is accumulated called the Galvanic fluid; and he likewiſe aſſerts, that by means of this Galvanic fluid the ſtate of the irritable capacity of a nerve or muſcle may be aſcertained, for which experiment a metallic ſtimulus, compoſed of zinc and ſilver, is neceſſary. According to this chemical phyſiologiſt, many of the opinions of Girtanner on the ſubject of irritability are erroneous; for, from various experiments, not only the irritability of the muſcular fibre is to be increaſed by ſubſtances that contain no oxygen, but he found that a fluid containing no oxygen increaſes the irritability of the fibre more than any other known irritable means. Thus, if two organs of equal irritability be dipped in an alkaline ſolution, and in oxydated muriatic acid, the firſt will become irritated to powerful motion, whilſt the other remains motionleſs; but according to the theory of oxygen, as a material principle of irritability, the contrary might be expected. Similar appearances take

place when alcohol, muſk, camphor, tartar emetic, and muriated barytes, are uſed; ſubſtances ſuppoſed to contain little or no oxygen.

With reſpect to bodies that increaſe or diminiſh irritability, he found,

1ſt. That all bodies containing oxygen increaſed or *augmented* the irritability of the nerves, ſuch as the oxygenated muriatic acid, oxyd of arſenic, &c.

2d. That all bodies which abſorb oxygen diminiſh or *leſſen* this irritability; ſuch as the ſulphuret of potaſh, ſolution of potaſh, nitrous gas, &c.

With reſpect to the *firſt*, if a large nerve be laid bare, as the crural, and if it be touched with ſubſtances containing oxygen, as the acids, it ſhows an irritability. The ſame takes place with very irritable muſcles; as the heart of a frog, when it's motion begins to diminiſh, by being plunged into an acid liquor, ſuch as the oxygenated muriatic acid, has it's irritability reſtored to it.

With reſpect to the *ſecond*. If this heart, however, remains too long in the acid, it's irritability is too much increaſed, by receiving too great a quantity of oxygen, and the motions ceaſe. To make them therefore reappear, ſubſtances muſt be employed that can abſorb this exceſs of oxygen, ſuch as the ſulphurets of potaſh, alkalis, &c. Thus, by moiſtening the heart by the ſulphuret of potaſh, it's motions recommence. But the abſorption of oxygen ſoon takes away all irritability: hence the motions ceaſe again; and, to make them reappear, the oxygen muſt be rendered to it again, by dipping it in the oxygenated muriatic acid.

He found that heat, alcohol, &c. equally reanimate the actions of the heart; that the arterial blood produces the ſame effect, from it's containing oxygen, but not the venous blood. If the nerve of a part be tied, it loſes it's irritability; and the ſame happens if the artery be tied,

which carries the blood to it, as Haller has proved. The explanation this chemical phyfiologift gives of thefe facts is the following. He lays down three principles as neceffary to excite the irritability.

1. *Oxygen,* which forms combinations with different acidifiable bafes.

2. The *acidifiable bafes* of the fibre with which the oxygen may combine. Thefe acidifiable bafes are, *carbon,* with which it forms carbonic acid, or oxyd of carbon; *hydrogen,* with which it forms water, or oxyd of hydrogen; *azot,* with which it forms oxyd of azot; *phofphorus,* with which it forms oxyd of phophorus.

3. The *Galvanic fluid.*

Thefe combinations, however, of oxygen with the acidifiable bafes of the fibre cannot take place alone, the fame as azot and oxygen mixed together do not produce nitric acid; but if the electric fpark is made to pafs through this mixture, the azot and oxygen combine, and the product is the nitric acid.

The Galvanic fluid produces, according to Humboldt, the fame effect in the animal economy as the electric fluid in the mixture of azot and oxygen. It is this Galvanic fluid that, being conveyed by the nerves, brings about the combinations of the oxygen with the different acidifiable bafes of the fibre; but when the nerve of a part is tied, it prevents the fluid from paffing, which explains the reafon of the irritability being deftroyed.

The oxygen neceffary for thefe unions is carried by the arterial blood in the courfe of circulation; and the acidifiable bafes which are to unite with it are found to be already prefent in the fibre.

He found that every thing that augments too much the quantity of the acidifiable bafes diminifhes the irritability, and that every thing that increafes too much the quantity of oxygen likewife diminifhes it; and he thinks it very

probable that the ſame takes place with reſpect to the proportion of the Galvanic fluid.

It is therefore only in a juſt equilibrium of theſe principles that the neceſſary irritability of the parts conſiſts; and the manner of it's operation this phyſiologiſt thinks may be conceived in the following way:

Suppoſe a fibre to be compoſed of the following particles *oooooo*, which are acidifiable baſes, azot, hydrogen, carbon, phoſphorus; the arterial blood then carries the oxygen to them, and the Galvanic fluid, conveyed by the nerves, making a diſcharge into the muſcles, the acidifiable baſes combine by this means, and they approach each other from their affinity becoming ſtronger, and the fibre is then ſhortened and contracted. In order to conceive the manner of the diſcharge in the internal part of the body, it is neceſſary to call to mind the manner of it's action externally.

For inſtance, let the nerve be *a p m*, which is diſtributed in the muſcle *o o*. The portion *m* of the nerve which is diſtributed in the muſcle *o o* communicates to it a portion of it's Galvanic fluid; whilſt the portion *p a* ſuppoſed to be detached from the muſcle, and ſurrounded by air, which is not a conductor of this fluid, preſerves it wholly. This portion *p a* contains, then, more Galvanic fluid than the muſcle *o*. If, therefore, theſe two portions be directly put into contact, there will immediately be a diſcharge of the Galvanic fluid, which will paſs from the nerve *a* into the muſcle *o*.

The irritability may be likewiſe excited by eſtabliſhing a communication between the nerve and the muſcles by means of animal ſubſtances, as conductors, ſuch as pieces of fleſh or of nerve; alſo by placing a homogeneous metal, moiſtened on one ſide with an evaporable fluid, as water, between them.

It is the ſame with reſpect to muſcular motion internally.

In a ſtate of repoſe, the nerve being inſerted in the muſcles, the galvanic ~~gaſtric~~ fluid is put into an equilibrium in the organs that touch each other. The ſpontaneous motion is made by a ſurcharge of Galvanic fluid into the nerve. It appears that, the inſtant we wiſh to make a motion, the Galvanic fluid produced in the brain is carried in maſs towards the part that ought to move, and ſurcharges the nervous fibres. A diſcharge from the nerve is then made into the muſcles. The particles of theſe laſt, animated by increaſed affinities, approach each other, and it is this that conſtitutes the phænomena of contraction. The acidifiable elements, azot, hydrogen, carbon, and phoſphorus, of which the muſcular fibre is compoſed, combine amongſt themſelves, and with the oxygen of the arterial blood. Muſcular motion, therefore, is productive of an aqueous fluid, as ſweat, carbonic acid, nitric acid, oxyd of phoſphorus, ammonia, ſoda. The Galvanic fluid being decompoſed, or rendered latent by contraction, and the chemical phænomena that accompany it, the particles of the muſcle reenter the ſphere of their primitive attraction.

If the Galvanic fluid is carried away without the direction of the will (as is the caſe in diſeaſes), and in too great quantity to one part, it gives riſe to ſpaſm and convulſion, which laſt has been put a ſtop to by the touch of metallic ſubſtances, which, being conductors of the Galvanic fluid, diſſipate it. It is upon this principle, according to Humboldt, that Perkiniſm is founded, or the method of curing diſeaſes by metallic points. Dr. Raſn of Copenhagen has publiſhed a book on this ſubject. The manner of uſing them is to preſent them to the diſeaſed part, and relief is ſaid to have been the conſequence. The metallic points are commonly made of ſteel or ſilver, and are uſed in different manners. If by theſe the patient has in reality been relieved, it may be ſuppoſed to have ariſen from diminiſhing or increaſing the Galvanic fluid in the

part relieved; and it is perhaps on the ſame principles that magnetic plates have produced the good effects on applying them in the ſame manner to the diſeaſed part, if it be true that cures have been effected by them.

Muſcular motion, from what has been ſaid, always ſuppoſes an abundant emiſſion of the Galvanic fluid, and the ſame is the caſe with all the other functions. Thus digeſtion only operates by the Galvanic fluid, which renders the gaſtric powers active. Thought alſo equally requires the Galvanic fluid, which is conveyed to the place where it is to be put into execution: hence, in the time of digeſtion, it is to be ſuppoſed that thought either cannot take place, or that it ſhould turn the Galvanic fluid elſewhere, and the digeſtion be diſturbed. And as thought likewiſe requires a great deal of Galvanic fluid in the thinking organ, it is neceſſary that all the other motions, except the vital, be ſuſpended, or *thought* cannot be made freely.

On this hypotheſis, therefore, the different animal functions are a ſeries of continual combinations made in the body.

The chief principles of the animal fibre, according to the ingenious philoſopher Davy, appear to be nitrogen, hydrogen, carbon, oxygen, and light. He thinks the immediate cauſe of irritable action to be moſt probably the combination of the oxygen with the hydrogen and carbon forming water and carbonic acid, and liberating the azot and electric fluid; ſince it is certain that water and carbonic acid are liberated during muſcular action; and probably azot, and light in it's condenſed ſtate electric fluid; as it is well known that the torpedo and ſome other animals give out the electric fluid during animal action. He thinks that in man the quantity is probably too ſmall, and too ſlowly liberated, to be aſcertainable. He looks upon the laws of mind to be moſt probably not different from the laws of corpuſcular motion; that every change in Davy.

our ſenſations muſt be accompanied with ſome correſpondent change in the organic matter of the body; but theſe changes an extenſive and philoſophic chemiſtry muſt enable us to find out; that, by the diſcovery of them, we ſhould be informed of the laws of our exiſtence, and probably enabled in a great meaſure to deſtroy our pains and increaſe our pleaſures. Thus would the ſcience of chemiſtry become the moſt ſublime and important of all.

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Reſpiration.

Reſpiration.—The proceſs which nature employs to oxygenate the blood, by means of the lungs, is called reſpiration; a function not only enjoyed by the animal, but alſo in ſome degree by the vegetable creation; and ſo eſſential is it to life, that wherever vital organization is fonnd to exiſt there is no exception to the general rule.

Compoſed of two actions, inſpiration and expiration.

This function is compoſed of two actions; the dilatation of the thorax, by which a quantity of air is received into the lungs; and it's contraction, by which the air is expelled from them: and theſe two actions take place alternately. According to the preſent theory of reſpiration, inſpiration

is the means of communicating the oxygen of the air to the blood, which, in confequence, is changed from a dark to a fluid red colour, and there is an extrication of caloric producing animal heat. Expiration, on the contrary, is found to convey what might be hurtful, fuch as fixed air and aqueous vapour out of the lungs.

In all animated beings, the final intention of this function is the fame; but on examining the parts in different claffes of animals, the organs by which refpiration is produced are exceedingly varied. On taking, however, a general view, perhaps the moft fimple divifion of the refpiratory organs will be the following.

Divifion of the organs.

1. Lungs, as in man; quadrupeds of the two orders; birds; and the cetaceous clafs.

2. Gills, as in fifhes.

3. Stigmata, or holes in different parts of the body, as in infects.

Of thefe three fpecies there are great varieties of form, but the office in which they are employed is the fame; thus the varieties of the firft and laft fpecies of refpiratory organs communicate the oxygen to the blood by the atmofphere, whilft thofe of the fecond fpecies communicate it by water.

There are two obfervations which have been made upon the refpiratory organs of animals.

Obfervations on the different organs of refpiration.

I. The quantity of blood is found to be in a given ratio to the perfection of their refpiration, whilft the difference of the circulatory organ or heart is always in a ratio to that obferved in the refpiratory organ; both of thefe functions undergoing, in fome meafure, a gradual degeneration in the different claffes of animals, and the animal heat keeps the fame ratio; hence a fcale may be formed of thefe gradations in the following manner.

1. Quadrupeds. 2. Cetacea. 3. Birds.	4. Ovip. Quad. 5. Serpents 6 Fifhes.	7. Infects. 8. Worms.
Blood in large quantity, and hot.	Blood in fmall quantity, and nearly cold.	A white liquor inftead of blood.
Two ventricles in the heart.	One ventricle.	Heart of different forms, or unknown.
Refpire by lungs, and frequently.	Refpire at long inter vals; fome by lungs, others by gills in their imperfect ftate, and others always by gills.	Refpire by ftigmata, or by unknown means.

1. Of quadrupeds, cetacea, and birds, the laft have the moft extenfive lungs, and they are found to exceed the two other orders in poffeffing a higher temperature; but this perfection of their refpiration, as it has been called, has it's difadvantages; and they are the firft to feel the bad effects of noxious airs, which have been proved by experiment to be fooner fatal to them than to the others.

2. Oviparous quadrupeds, ferpents, and fifhes, have their blood ftill lefs warm, their lungs fmaller; and whether gills or lungs, a fmaller quantity of oxygen is of courfe communicated to their blood, which is lefs in quantity than in the before-mentioned orders. Of the oviparous, who can ftop their refpiration for forty or fifty minutes, and upon which animals experiments have been made, they are found to refift even carbonic acid gas for a great length of time, and do not die in lefs than fifty minutes; a fmall portion of blood only paffes through their lungs, the reft being conveyed immediately from one ventricle to another. Fifhes have likewife lefs blood in proportion to their bulk than quadrupeds, which agrees very well with their imperfect refpiratory organs. In thefe, however, there is great variety. Thus the cartilaginous fpecies of fifhes that have their refpiratory organs more extended than others have likewife a larger proportion of blood. The pike, alfo, the organs of which are more complete that thofe of the

carp, contains more blood, but cannot live fo long out of water; and the carp, refpiring in a more perfect manner than the eel, is likewife furnifhed with more blood.

3. With refpect to infects the difference is more ftriking; their heart is membranous, fcarcely fufceptible of motion, and inftead of lungs they have only veffels diftributed to different parts of the body. Their blood, if it can be fo called, has not that red colour which characterizes that fluid in other animals; but they are very tenacious of life, and are not eafily deftroyed on refpiring noxious airs. Thus, according to Young, animals of this order, as wafps, &c. when expofed to carbonic acid gas, although they become torpid at firft, foon recovered from their lethargy, and appeared to fuftain the effects of the air without any inconvenience.

II. The fecond obfervation which has been made refpecting the organs of refpiration is, that the more perfect refpiration is, the more are it's organs concealed. Thus birds, whofe refpiration is fo perfect, at leaft according to Brouffonet, have the air conducted even into the cavities of the greater part of their bones; and confequently their organs are more internally fituate than thofe of quadrupeds, in which the lungs only, defended by the thorax, are more concealed than thofe of the oviparous tribes, the refpiratory organs of which are placed externally during the firft period of their life, and internally the remaining part, when their metamorphofis obliges them to breathe the atmofpheric air. The organs of fifhes, or their gills, are nearly uncovered, and may be feen without deftroying or taking away any part; but as they breathe in a more perfect manner than the mollufca and aquatic fhell-fifh, their organs are even more concealed; in which laft they are moft commonly fituate externally, and are perfectly expofed. It is in thefe that this function appears to be nearly effaced; and, in order to dif-

cover it, we can, in general, be guided only by analogy. In the vegetable tribes the leaves are their refpiratory organs, and are only of ufe during a part of the year: in winter they are deprived of them. The abfolute neceffity of breathing muft certainly have been known to the earlieft ages of antiquity: it's great importance feems even to have been acknowledged by Mofes:—"And the "Lord God formed man of the duft of the ground, *and "breathed into his noftrils the breath of life, and man became a living foul.*" Gen. ii. 7.—But the difcovery of it's ufe, and more particularly the procefs which is carried on in the fyftem during refpiration, is, like moft other difcoveries of the firft magnitude, only of modern date; nor could the ancients have been capable of forming any tolerably precife idea of the fubject, from their ignorance of the nature of the atmofphere itfelf. We are informed by Diodorus Siculus, it was an opinion amongft the ancient Egyptians, that the atmofphere was incorruptible; that it was of fuch extent as to reach even unto Heaven; that it's moft important office was in concurring towards the generation of all animals; and it appears, from the epithet of Glaucopis, which they gave to the goddefs of the air, that they confidered the blue firmament as peculiar to it's colour. This opinion of air being the principle of all bodies was fupported by many Greek philofophers, fuch as Anaximenes, Diogenes of Apollonia, and Archelaus the mafter of Socrates. From the nature of air being fo little underftood, it cannot be fuppofed that their notion of refpiration could be very exact; and we are informed that Empedocles was of opinion it was brought about principally by the nofe, and that it was determined by the void, which the motion of the blood alternately operated in a part of the veins.

Knowledge of the ancients on this fubject.

Notwithftanding the imperfect knowledge of the ancients refpecting this function, they knew very well how

indiſpenſable the neceſſity of air was to the ſupport of life, that neither animal nor plant could live without it. They knew that when animals had remained a certain time in a given quantity of atmoſpherical air, they began to languiſh, and become to all appearance ſleepy; that this ſleep was at firſt peaceable, but was ſoon followed by great agitation; that reſpiration then became difficult and precipitate, and that death ſucceeded in convulſions. Theſe facts were well known to Ariſtotle, Eriſtratus, and Aretæus. Hippocrates reckoned air a ſpecies of aliment that was neceſſary to the animal ſyſtem. The opinion, however, which appears to have prevailed the longeſt and moſt univerſally amongſt the ancients, was, that reſpiration is chiefly intended to temper the blood, and carry off the fuliginous vapours with which it is loaded by the vital fire conſtantly kept up in the heart. This hypotheſis was ſtrongly ſupported by Galen. Four ages after Ariſtotle we find the knowledge of this ſubject ſcarcely any further advanced. Pliny calls the air the vital ſpirit, and Cicero affirms that the heart imbibes a ſpirit from the air. Among the moderns, Deſcartes revived the hypotheſis which Galen had ſo well ſupported, and maintained the ſame vital fire in the heart, ſuppoſing that air was neceſſary to cool and condenſe the blood. Borelli reckons the great uſe of reſpiration to conſiſt in the admiſſion and mixture of air with the blood, in order to inform thoſe elaſtic globules of which it is compoſed, to give it it's florid redneſs, and to prepare it for many purpoſes of the animal œconomy. Bathier was of opinion that, during reſpiration, the more ſubtile and elaſtic particles of the air were imbibed, and the cruder part expelled through the pores of the pulmonary arteries into the trachea. Van Helmont aſcribed the volatility of the fixed elements in the food to this air; and Stephenſon thought that the air which had circulated in the blood, and which had heated

Ariſtotle. Hippocrates. Galen. Pliny. Cicero. Deſcartes. Borelli. Bathier. Van Helmont.

Boyle. it too much, was exhaled by the lungs. Boyle and others thought that the air itfelf is not admitted to the blood, but that fome active, fpirituous, and ethereal particles were communicated to it; that this vital fpirit paffes from the lungs to the heart and arteries, and at length becomes the animal fpirits, which are, by this means, generated by the air. Thofe, on the contrary, who did not admit that the animal fpirits are derived from the air, ftill fay that fome other *vital principle* comes from thence. This vital principle, imbibed from the air, Malpighi calls a faline vapour; Lifter, an inflammable fulfureous fpirit; Vieuffens, a volatile acid falt, which keeps up the fermentation of the blood; and Bryan Robinfon, that it is the aërial acid which preferves it from putrefaction, and gives ftrength to the animal fibres. Hence he fuppofes it is that we feel ourfelves refrefhed in cold air, as it abounds with a more acid quality. But of all the opinions that have been given refpecting the function of refpiration, the theory of Mayow is the moft deferving of attention.

Mayow. This celebrated philofopher lived about the middle of the 17th century. He was contemporary with Boyle, Lower, and Willis; and fo acute was his obfervation of natural phænomena, and fo juft his judgment on the caufes which produced them, that, with refpect to refpiration, Dr. Beddoes has very properly obferved he has, in fome meafure, anticipated the difcoveries of the prefent day. His works give an account of the ufe of the air in combuftion and refpiration, or it's diminution and abforption by them. They affert, in a very clear and pofitive manner, the abforption of one part of the air by the blood, which he calls the vital part, as well as the warmth of this fluid produced by this abforption, or by the prefence of air in the lungs. Mayow has likewife fhown that the red colour of the blood, and the change of the venous into arterial blood, depend entirely on the contact of the atmo-

ſpheric air; and had he known how to have extracted the vital air of the atmoſphere from the ſubſtances that abſorbed it, had he but known it's properties when in it's pure and iſolated ſtate, he would have eſtabliſhed all the principles of the preſent theory of combuſtion, reſpiration, and the formation of acids, general ideas of which are to be found in his works.

It appears from theſe, that 120 years ago he had imagined an apparatus by which he could determine that the air was in part fixed, or diminiſhed, and abſorbed by combuſtion and reſpiration; that theſe two phenomena acted upon it in the ſame manner; and that there was only one part of the air, the moſt ſubtile and elaſtic, which may be called vital, and that ſerved both for inflammation and reſpiration. "What confirms our hypotheſis," ſays he, "is, that the air, on coming from the lungs of animals, "is found diminiſhed in it's elaſtic force on account of it's "nitro-aerial principles being exhauſted by reſpiration: "theſe experiments will prove the laſt aſſertion. Attach "a wet bladder to the circular edge of the orifice of a "veſſel, like a ſkin extended on a drum; place a ſmall "cupping-veſſel containing a mouſe upon this bladder, "and load it with a weight to prevent the animal over-"throwing it. A few inſtants afterward you will ſee the "cup adhering ſtrongly to the bladder, and this puſhed "into the veſſel as if the flame had been under it. This "phenomenon will take place whilſt the animal ſtill "breathes. If you attempt to take away the cup, you "will raiſe at the ſame time the bladder, which ſtrongly "adheres to it, and with it the veſſel it covers, unleſs it "be too heavy: and, in effect, a mouſe put into a cup-"ping-veſſel, and applied to the ſkin, is able to ſupply, "to a certain point, the flame which it is cuſtomary to "produce in it. The reſult certainly is, that the elaſ-

" ticity of the air contained in the veſſel has been dimi-" niſhed by the reſpiration of the animal, in ſuch a man-" ner as no longer to ſuſtain the preſſure of the atmo-" ſphere.

" To give a better conception of this reſult, we ſhall " add another experiment analogous to it, which will " ſerve to determine what fraction, what part of the air, " deprived of it's vital particles by reſpiration, is diminiſh-" ed in it's volume. An animal is to be placed in an in-" verted glaſs, or ſuſpended in a priſon or grate at the " top of a glaſs cucurbit: the orifice of the cucurbit is " then placed in a jar, and plunged into water, in ſuch a " manner as this may riſe to the ſame height as externally, " which may be attained by the aſſiſtance of a crooked " ſyphon already deſcribed: the exterior water is to be " ſomewhat voided, ſo that the water in the cucurbit may " be better ſeen; the height of which is to be marked by " a paper glued upon the outſide of the veſſel. The " water ſoon riſes in the cucurbit, and continues to riſe " by degrees, although the heat produced by the animal, " and the exhalations produced from it's body, would ſeem " to produce a contrary effect. In order to terminate the " contraction the air in the veſſel undergoes before it is " become incapable of ſupporting the life of the animal, " the following method may be employed: the ſpace oc-" cupied by the air is to be meaſured at the moment the " mouſe is introduced, and afterward that to which it has " been reduced after the ſuffocation of the animal, and " the aſcent of the water, which is done by the volume " of water employed to fill theſe ſpaces: leaving the ap-" paratus in the ſame ſtate, the height of the firſt ſpace " above the ſecond is then to be calculated, and the dif-" ference is the meaſure of the volume and of the elaſticity " diminiſhed by the reſpiration of the animal. I am

"aſſured by different experiments made with different "animals, that the air loſes about one fourteenth of it's "volume by reſpiration.

"It is then very evident, that animals in reſpiring abſorb "certain vital and elaſtic particles from the air. There is "no doubt but that there enters, by reſpiration, ſome-"thing aerial into the blood of animals which is neceſſary "to life. It is not only for the attrition of the blood that "the lungs and their functions are deſtined, &c. nor is "it certain whether this aerial principle is abſorbed by "the capillary tubes, or the extremities of the ſanguineous "veſſels: but the air is not leſs deprived of it's elaſticity "by reſpiration than by combuſtion; and there is reaſon "to believe that animals take particles of the ſame ſort "as fire does from the air, as the following experiment "proves.

"If an animal and a lamp be encloſed in a glaſs veſſel "which has no communication with the external air, "which is eaſily done by inverting this veſſel into water, "the light will ſoon be extinguiſhed, and the animal will "not reſiſt a long time this *cruel torch*, tædæ ferali. I "have found by obſervation, that an animal encloſed in the "ſame glaſs with a lamp does not breathe longer than "half the time it would have done if alone: It is not the "ſmoke which ſuffocates it; for ſpirit of wine, that affords "no ſmoke, produces the ſame effect: but the air, yield-"ing it's nitro-aerial particles to the flame, can no longer "furniſh the animal with them. This has no occaſion "for ſo many igneo-aerial particles as the lamp; for the "lungs, as it were, go in ſearch of them to abſorb them: "as to the flame, it is neceſſary for them to be near it, "preſent themſelves, and be inceſſantly renewed: hence "the animal exiſts ſome time after the extinction of the "lamp, and when the aerial particles are almoſt entirely "exhauſted. It is on that account that the air in which

" the animal is fuffocated undergoes more than twice the
" diminution of that in which a candle is extinguifhed,
" as has been feen. I have tried in vain to light again, by
" the affiftance of a burning glafs, the combuftible matter
" contained under the fame veffel as the animal that had
" expired; and although it is poffible that the foggy feafon
" of the winter may have produced fome incertitude in
" this experiment, it is not lefs probable that the air
" which is no longer proper to fupport the life of animals
" is no longer fo to fupport flame, fince more aërial par-
" ticles are neceffary for the inflammation of the lamp
" than for refpiration: it is however not to be concluded
" from hence that the mafs of blood is in a real combuf-
" tion."

He alfo obferves, that mice and birds placed towards the fuperior part of the cucurbit died fooner than thofe in the inferior part; and that in the firft cafe the water did not rife fo high. He obferves, that if two animals be put at the fame time into the fame veffel, the one in the top part and the other below, the firft foon dies, and the other furvives it for fome time; from which he concludes that the air, deprived of it's nitro-aërial particles, is become lighter, and that the part of it which ftill preferves them occupies the inferior part of the veffel. He fays, therefore, that an animal which begins to fuffer from want of air raifes it's head towards the upper part of the veffel; but finding itfelf more affected in this place, it immediately plunges it's head below again, and keeps it fixed at the bottom. He applies the fame remark to a candle, which, when carried to the top of the veffel, is extinguifhed much fooner than below, becaufe the air becomes incapable of fupporting the flame; and fince it is become at the fame time lighter than the atmofpherical air, it is pufhed towards the top of the cucurbit, and not permitted to depart; which proves that the air is deprived

of certain ſolid and heavy particles by inflammation and reſpiration, ſince it acquires lightneſs on coming from the flame and the lungs.

He likewiſe obtained, without knowing it, nitrous air or gas (by the means of iron wire and the nitrous acid); and having obſerved the diminution of air by this gas, he with reaſon compares this effect to that produced by candles and reſpiration, fifty years before Hales had obſerved the ſame, and a century previous to the diſcovery of Prieſtley reſpecting nitrous air, and it's property of forming nitrous acid with the vital air of the atmoſphere. He is of opinion, that the nitro-aërial ſpirit is condenſed in the ſame manner by the blood as by the iron-wire in the nitrous acid (by which he procured the gas), *i. e.* by fermentation: hence it is to the ſanguineous fermentation that he attributes the ſame condenſation in reſpiration. He thinks that the fermentation of the blood is produced by the condenſation of the nitro-aërial ſpirit, and this condenſation by the fermentation of the blood; for, the particles of this ſpirit once condenſed, he admits their introduction into the maſs of the blood; and to theſe he attributes it's red colour, it's heat, and fluidity. It is on this account, he ſays, that the blood is black in that part which does not touch the air, and very red in that part which is in contact with it; that the venous blood is black, and the arterial of a ſplendid red; that violent exerciſe heats, by multiplying the inſpirations; that a perſon becomes warmer by voluntarily increaſing his reſpiration; that the fevers of conſumptive people ariſe from the force with which the pus of the lungs attracts and abſorbs the nitro-aërial ſpirit, with which it produces a great fermentation; that, venous and arterial blood being placed under the vacuum of Boyle, the firſt only offers a few blebs, whilſt the ſecond is totally converted into foam. He adds, that this nitro-aërial ſpirit gives the red colour to

bodies in which it exifts, as to the fuming fpirit of nitre. He compares the heat produced by the condenfation of this fpirit in the lungs, with that produced by pyrites in effervefcence; and he attributes the vitriolization to the fame caufe.

Such are the principal facts which Mayow delivered to pofterity, at a time when the fubjects on which he treated were little underftood, and his experiments ftill lefs fo, by the age he lived in. No philofopher, at the end of the laft century, had given any theory of combuftion and refpiration, or any account of the analogy between thefe two natural phenomena; of the reciprocal influence between them and the air; and of the effects produced by this fluid compared with thofe of nitre on combuftible bodies, with fo much detail and fagacious ingenuity as this phyfician. His works form an epoch in the annals of refpiration. In giving Mayow all the merit due to him, it appears, however, that although he had determined with great precifion the ufe of the nitro-aërial fpirit of the atmofphere to be to warm the blood and give it it's brilliant red colour, he was ignorant whence thefe phenomena arofe, and how the air contributed to it: and although thefe nitro-aërial and igneo-aërial particles may be looked upon as the vital air or oxygen gas of the moderns, he knew nothing of it's properties, nor the change it underwent by the action of flame and refpiration. Thefe explanations were referved for Prieftley and Lavoifier.

Malpighi. Malpighi has been already mentioned. It was a received opinion, that one ufe of the lungs was to attenuate the blood; and, according to Malpighi, the different parts of the blood by this means become thoroughly mixed together; while others were of opinion, that the blood is condenfed in the lungs; and others, that the globules and all the finer humours receive their configuration

there. Some, without confidering the air as of any other ufe than to put the lungs in motion, thought that heat is produced in the lungs by the attrition of the blood in paffing through them. The red colour of the blood has been thought by fome to be caufed by this attrition in the lungs; but Lower refuted this notion, chiefly by obferving that the attrition of the blood is greater in the mufcles, from which, however, it always returns black. Whytt thought there was fomething of a vital and ftimulating nature derived from the air into the blood. Sir Ifaac Newton imagined that the atmofpheric air might communicate an acid vapour to the blood in the lungs, which was neceffary to keep up the action of the heart. According to Boerhaave, air which has not been changed is deadly; not on account of heat, rarefaction, or denfity, but from fome other *occult caufe*.

Lower.

Newton.

Boerhaave.

Dr. Hales, who, if we except Mayow, has thrown more light on the doctrine of air than any of his predeceffors, was equally ignorant of the ufe of it in refpiration, and feems to have adopted, at different times, different ideas of it. It appears, from various paffages in his Statical Experiments, that he believed the red particles acquire confiderable degrees of elaftic vibrations, if not an electrical virtue, in paffing through the lungs; "for (fays he), while by the extraordinary frictions they "undergo they are much heated and dilated, they are at the "fame time refrigerated and contracted by the frefh air "that is continually taken into the lungs; for the coats of "the veficles are fo extremely thin, that thofe two fluids are "fuppofed to be 1-1000th part of an inch within contact "of each other: fo that, like blended liquors, they muft "needs have a confiderable effect upon each other; the air "in cooling the blood, and the blood in warming the air." He is likewife of opinion, that the red colour of the globules intimates their abounding with fulphur; that the

Hales.

air is rendered alkaline by breathing; and that suffocation is owing to the collapsing of the minute vesicles of the lungs, in consequence of the confined air being deprived of elasticity, and the contraction occasioned by the stimulating sulphureous vapour. He says the venous blood is not florid; which floridness in the arteries may be owing to the greater velocity with which it passes through the lungs than other parts of the body; for blood agitated much in a closed vessel was observed to become very florid, even as much as arterial: but the great purpose of the lungs is to refrigerate the blood.

H. ller. Haller, after giving the opinions of all that went before him, says that the use of the lungs is partly inhaling and partly exhaling; that the lungs *inhale* both water and air, but that in them the air loses it's elastic property, so as to be easily soluble in water or vapour; and he thinks it probable that the air serves as a cement to bind the earthy parts together. He does not doubt but that various other matters, miscible with water, are inhaled by the lungs; and he thinks it not improbable but that the air may carry some electric virtue along with it. The principal *exhalation* of the lungs he thinks to be water, abounding with oily, volatile, and saline principles; and these oily and fœtid vapours, he thinks, are the *fuligines* of Galen and the ancients.

Cigna. Cigna, in a work *De Respiratione*, takes it for granted that air which has been once respired becomes unfit for further respiration, because it is loaded with noxious vapours, to be known by their fœtid smell. He says that air is diminished by respiration; and that air which has been breathed suffocates by means of the irritation it occasions to the lungs, by which the bronchia, and the lungs themselves, are contracted so as to resist the entrance of the air; and therefore that respired air is noxious on the same account as mephitic vapours, or those of burning sulphur:

that in frequently breathing the fame air it becomes fo loaded with thefe vapours as to excite a convulfion of the lungs, and thereby render them unfit for tranfmitting the blood. He fuppofes that air enters the pores of the blood, retaining it's elaftic power; and that it continues at reft there, becaufe it's endeavour to efcape is counteracted by the equal preffure of the ambient medium. This air he thinks is introduced by the chyle, and never by the way of the lungs, except when, by fome means or other, the equilibrium between the air in the blood and the external air is loft. If the external air be rarer than the internal, the air in the blood, expanding itfelf, will inflate the animal, and have the fame effect as air introduced into the veins.

Upon the whole, he concludes that the principal ufe of air to the *blood* is to preferve the equilibrium with the external air, and to prevent the veffels from being rendered unfit to tranfmit the blood, on account of the external preffure; whereas, by means of the air they contain, the fluids move in their proper veffels as freely as in *vacuo*, and the membranes and vifcera alfo eafily flide over each other. With refpect to the ufe of the lungs, fince he imagined that air is not introduced into the blood by means of them, he thinks that becaufe fuch lungs as thofe of men are given to the warmer animals only, the chief ufe of repiration is exhalation, and confequently the cooling of the blood.

On cafting the eye over the variety of opinions which for fo many centuries have taken place of each other refpecting the ufe of refpiration, it may appear fomewhat extraordinary that no one fhould have been fo fortunate, if we except Mayow, as to conjecture rightly; but this furprife will be diminifhed on confidering, that, before any real light could be thrown on this obfcure fubject, it was neceffary that the nature and component part of the atmo-

ſphere we breathe ſhould be inveſtigated and made known. Some chemical philoſophers were engaged at the ſame time upon this intereſting ſubject, and their labours upon the air and the different gaſes have been crowned with ſucceſs. A pure aërial principle was found to exiſt in the air much about the ſame time by Dr. Prieſtley, who called it *dephlogiſticated air*; by Scheele, who named it *empyreal air*; and by Lavoiſier, who gave it the name of *highly reſpirable* or *vital air*: and as it was afterward found by the French chemiſts to be the acidifying principle to the baſis of acids, they call it *oxygen*, or, in it's combination with caloric, *oxygen gas*. What therefore was only conjectured by Mayow to form a part of the atmoſphere, has been proved, beyond a doubt, to be the great agent in the office of reſpiration; and as Boyle, Hales, Black, and Prieſtley, may be conſidered as the firſt who obſerved with accuracy that reſpiration exerciſes an evident action on the atmoſpheric air, that it diminiſhes it's volume and changes it's nature, and that, in a very ſhort ſpace of time, the fluid made uſe of by this function loſes the property of ſupporting any longer the life of animals, a clew was preſented to the chemical phyſiologiſt that would lead him to account for all theſe phenomena.

Diſcovery of oxygen gas in the atmoſphere.

Stahl's phlogiſton.

At the time of the diſcovery of *oxygen*, as compoſing a part of the atmoſphere, the prevalent doctrine was that of Stahl. Beecher had imagined a ſubſtance to exiſt in inflammable bodies, which is the principle of inflammability, and which is called *phlogiſton*; and the genius of Stahl had matured this into a theory, by which he accounted for almoſt every chemical phenomenon. The phlogiſtic fluid was either imbibed by or extricated from every thing. The ſectaries of Stahl applied this doctrine to explain the effects of reſpiration; and they ſuppoſed that, during the action of this function, a certain quantity of phlogiſton was exhaled from the blood as it paſſed through the lungs,

which they ſaid phlogiſticated the reſpired air in the ſame manner as they had admitted it's phlogiſtication by combuſtion, the calcination of metals, and other proceſſes which they called phlogiſtic.

Amongſt theſe philoſophers was Dr. Prieſtley. He informs us, that the property in the air which contributes to the ſupport of life, and the reaſon that air which has been much reſpired will no longer ſerve that purpoſe, were not diſcovered by any body; and they might have continued to elude all *direct inveſtigation*, when they diſcovered themſelves in the courſe of experiments upon airs which had at firſt quite another object. According to this philoſopher, in the experiments it clearly appears, that reſpiration is a phlogiſtic proceſs, affecting air in the very ſame manner as every other phlogiſtic proceſs, ſuch as putrefaction, the effervefcence of iron filings and ſulphur, or the calcination of metals, affects it, diminiſhing the quantity of it in a certain proportion, leſſening it's ſpecific gravity, and rendering it unfit for reſpiration or inflammation, but leaving it in a ſtate capable of being reſtored to a tolerable degree of purity by agitation in water, &c. Having diſcovered this, he concluded that the uſe of the lungs is to carry off a putrid *effluvium*, or to diſcharge that phlogiſton which had been taken into the ſyſtem with the aliment, and was become, as it were, *effete*, the air that is reſpired ſerving as a *menſtruum* for that purpoſe. He thinks the uſe of reſpiration is confined to the blood, in conſequence of it's coming ſo nearly into contact with the air in the lungs, the blood appearing to be a fluid wonderfully formed to imbibe and part with that fluid called phlogiſton, changing it's colour in conſequence of being charged with it or freed from it, and affecting air in the very ſame manner, both out of the body and in the lungs, even when various ſubſtances are interpoſed which prevent it's coming into immediate contact with the air.

Dr. Prieſtley.

The black colour of blood Dr. Prieſtley accounts for as ariſing from imbibing phlogiſton, as may be ſeen from his experiments quoted on the colour of blood; and when he had found how readily pieces of blood changed their colour according to the quality of the air to which they were expoſed, the next thing was to examine the ſtate of that air, to find what change had taken place in it; and as dephlogiſticated air admits of a more ſenſible change of quality than common air, he gave it the preference, putting a piece of craſſamentum, about the ſize of a walnut, into about five ounce meaſures of this air.

This proceſs he continued twenty-four hours, changing the blood ten or twelve times; after which he found the air ſo far depraved, that whilſt, at the beginning of the experiment, one meaſure of it and two of nitrous air occupied the ſpace of no more than half a meaſure, the ſame mixtures afterwards occupied the ſpace of a meaſure and a half. Now, ſince air is univerſally depraved by phlogiſton, and in this ſenſe by nothing elſe, he thinks it is evident that this black blood muſt have communicated phlogiſton to the air, and of courſe it's change of colour from black to a florid red muſt have ariſen from this ſeparation of phlogiſton.

The next day, when of courſe the blood was nearer to a ſtate of putrefaction, in which every kind of ſubſtance will injure reſpirable air, he put a quantity of red blood tinged in a few places with black, which he could not eaſily ſeparate from it, to about the ſame quantity of the ſame dephlogiſticated air, and ſuffered it to ſtand, without changing, for the ſame ſpace of time; when it was ſo little injured that the meaſures above mentioned occupied the ſpace of only two thirds of a meaſure.

That blood has a power of taking phlogiſton from air, as well as imparting phlogiſton to air, he ſatisfied

himſelf by expoſing blood of a very beautiful florid colour to nitrous, inflammable, and phlogiſticated airs. The two firſt kinds of air were conſiderably diminiſhed by the proceſs, which was continued two days, and the blood changed five or ſix times.

The nitrous air loſt a great portion of it's power of diminiſhing, *i. e.* phlogiſticating common air: for now two meaſures of common air and one of this occupied the ſpace of two meaſures and a quarter, inſtead of one meaſure and three quarters.

The inflammable air, though ſtill inflammable, was rendered in ſome degree wholeſome by the proceſs; being after this conſiderably diminiſhed by nitrous air, which is a ſtate to which it is brought by agitation in water, and which, continued longer, deprives it of it's inflammability likewiſe. Hence, in both theſe caſes, the red blood, by becoming black, received phlogiſton from theſe two kinds of air. As to phlogiſticated air, Dr. Prieſtley only obſerved, that after a few hours expoſure to red blood it was ſenſibly, but not much, diminiſhed by nitrous air, which otherwiſe it would not have been in the leaſt degree. This blood, however, was of the lighteſt colour, or the moſt free from phlogiſton, of any he had ſeen: and he has tried the ſame thing, without ſucceſs, with blood of a leſs florid colour, though as florid as the common air could make it. But as the proper function of the blood is not to receive (meeting with no phlogiſticated air during circulation), but to communicate phlogiſton to air, there is not the ſame reaſon to expect that air will be mended by red blood, as that it will be injured by black blood. Dr. Prieſtley had imagined that, ſince black blood contains more phlogiſton than red blood, a ſimilar difference would have appeared in the air produced from them, either by being ſimply diſſolved in ſpirit of nitre, or when dried and made into a paſte with this acid,

But the difference was too fmall to be fenfible to this kind of teft. He ufed blood from the vein of a fheep, and from it's carotid artery. The quantity of air from the pafte was very great, and produced irregularly, as is the cafe when produced by a folution in fpirit of nitre without drying. Half the produce was fixed air, and the reft phlogifticated, except that a candle burned in it with a lambent blue flame. From this experiment, however, it is evident that even the moft florid blood contains a confiderable quantity of phlogifton, for otherwife this air would have been dephlogifticated. He found great difference in the conftitution of blood, with refpect to it's property of being affected by the influence of the air, fome becoming very foon of a light florid colour, and the ftratum of this colour foon growing very thick: others, in the moft favourable circumftances, continued much darker, and the lighter colour never penetrated far.

Being convinced afterwards of the reception of dephlogifticated air into the blood, befides the emiffion of phlogifton from it, Dr. Prieftley wifhed to determine *how much* of the dephlogifticated air enters the blood, a part of it being employed in forming the *fixed air*, which is the product of refpiration, by it's uniting with the phlogifton difcharged from the blood.

To determine what proportion of dephlogifticated air, deftroyed during refpiration, is employed in forming fixed air, it was neceffary to afcertain the proportion of dephlogifticated air and of phlogifton in the compofition of fixed air. He therefore

Heated charcoal of copper in 41 oz. m. of dephlogifticated air, of the ftandard of 0.33, till it was reduced by wafhing in water to 8 oz. m. of the ftandard of 1.33. Again, he heated charcoal of copper in 40.5 oz. m. of dephlogifticated air, ft. 0.34, till it was reduced to 6 oz. m.

ft. 1.76; and in each there was a lofs of 6 grs. of the charcoal of copper: fo there cannot be more than 6 grs. of phlogifton in 33 oz. m. of fixed air; hence very little more than one fourth of the weight of fixed air is phlogifton.

He heated perfectly well burnt charcoal of wood in 60 oz. m. of common air, and found one-fifth of the remainder to be fixed air, the refiduum, ft. 1.7. Laftly, he heated 8¼ grs. of perfect charcoal in 70 oz. m. of dephlogifticated air, ft. 0.46, when it ftill continued 70 oz. m.; but after wafhing in water it was reduced to 40 oz. m. ft. 0.6. and the charcoal then weighed 1¼ gr.: fo that from thefe experiments with common charcoal, as well as from thofe with charcoal of copper, about one fourth of the weight of fixed air is phlogifton, and confequently the other three fourths are dephlogifticated air.

Dr. Prieftley then wifhed to afcertain the quantity of fixed air formed in refpiration from atmofpherical and dephlogifticated airs, in order to determine if any part remained to enter the blood, after forming this fixed air.

For this purpofe he breathed in 100 oz. m. of atmofperical air, ft. 1.02, till it was reduced to 71 oz. m., and by wafhing in water to 65 oz. m. ft. 1.45. The computations made as before, it will appear that, before the procefs, this air contained 67.4 oz. m. of phlogifticated air, and 32.6 oz. m. of dephlogifticated air; that after the procefs there remained 53.105 oz. m. of phlogifticated and 11.895 oz. m. of dephlogifticated air, and there were only 6 oz. m. of fixed air produced, for the quantity abforbed during the procefs could only have been very inconfiderable. It will therefore be evident, that in this experiment 20.7 oz. m. of dephlogifticated air, which would weigh 12.42 grs., difappeared: whereas all the fixed air that was found would only have weighed 4.4 grs.

and one fourth of this being phlogifton, the dephlogifticated air that entered it would have weighed only 3.3 grs.: confequently 9.12 grs. of it muft have entered the blood; which is three times as much as that which did not enter, but was employed in forming the fixed air in the lungs.

He breathed in 100 oz. m. of dephlogifticated air, ft. 1.0 till it was reduced to 58 oz. m., and by wafhing to 52 oz. m. ft. 1.75, with two equal quantities of nitrous air. The computations being made, it will appear, that before this procefs this air contained 66 oz. m. of phlogifticated and 34 oz. m. of dephlogifticated air; and after the procefs there were 30.368 oz. m. of phlogifticated, and 21.632 oz. m. of dephlogifticated air. In this cafe, therefore, the dephlogifticated air that difappeared was 13.3 oz. m., weighing 7.8 grs., and the fixed air was 6 oz. m., weighing 44 grs.: fo that here alfo about three times as much entered the blood as did not.

Thefe experiments he repeated, and always with the fame refults; the greater part of the dephlogifticated air, but never the whole, paffing the membrane of the lungs, and entering the blood.

Dr. Prieftley is of opinion that part of the phlogifticated air entered the blood as well as the dephlogifticated, the dephlogifticated air confumed not being of the pureft kind. He thinks it very probable, that the deficiency of phlogifticated air was owing to the greater proportion of it in the lungs after the procefs than before.

When he breathed dephlogifticated air that was very pure, he generally found lefs lofs of phlogifticated air, and in one cafe there appeared to be an increafe of it; but there will always be fome uncertainty in the refults of the long continued refpiration of any kind of air, as the operation becomes laborious at laft, and the quantity of air infpired and expired is therefore greater than at firft. Being aware of this circumftance, he endeavoured to

obviate it's effects by leaving off with his lungs, as nearly as he could judge, in the fame ftate of diftenfion as when he began, which was always after a moderate expiration; fo that two or 3 oz. meafures would have made a very fenfible difference, as will be found by actual trial.—Such are the ideas of this celebrated philofopher on the function of refpiration.

The two great Swedifh chemifts appear to differ from Prieftley. Bergman and Scheele affirm, that the lungs, or the blood they contain, abforb phlogifton from the atmofpheric air, inftead of rendering it, and they have fupported this opinion by very ingenious experiments; fo that, according to them, the atmofpheric air, being deprived of it's phlogifton by the lungs, becomes incapable of entertaining life by ferving refpiration. Bergman. Scheele.

This ingenious Italian philofopher is of opinion, that he has proved, from experiment, that not only phlogifton is feparated from the lungs, but that fixed air is alfo difengaged from them; of which laft fact he looks upon himfelf to be the difcoverer. The office of refpiration, according to Fontana, is that of depriving the blood of a fuperabundance of it's phlogifton. He thinks that the caufe of fuffocation in refpired air arifes from two caufes; for, fince the air is found to be compofed of two parts, viz. fixed and phlogifticated airs, the fixed air acts upon the lungs and deftroys life, becaufe it is not only incapable of fupporting life, but acts as a real poifon, and may be called a pofitive caufe; and the phlogiftic air cannot entertain life, although innocent of itfelf, poffeffing no active power: but the animal dies in it merely through want of atmofpheric air; and this may be called a negative caufe. He thinks that one part of the fixed air expired by the lungs ought not to be attributed to the pulmonary phlogifton, as is generally believed, but that it is generated in the animal machine; whilft Landriani, in Fontana. Landriani.

oppofition, agrees with others, that it arifes from the expired phlogifton uniting with the a mofpheric air.

Lavoifier, from his experiments on different airs and on the air of the atmofphere, found that dephlogifticated air might be wholly converted into fixed air by the addition of powdered charcoal; and he read a paper to the Academy upon this fubject in 1775: he thought therefore that refpiration might be one procefs by which this is brought about; and having found that the atmofphere we breathe contains about one fourth part of vital air, and three fourths of azot gas, he fufpected that the dephlogifticated air, when taken into the lungs, is thrown out again in the form of fixed air; and that the other part, which enters the lungs, and paffes from them nearly in the fame ftate, without any alteration, is merely paffive.

Sufpecting, therefore, the theory of his contemporaries, and finding it contradictory to a great number of phenomena, he proceeded on a different plan, and was, by the confequences of his experiments, led to form different conclufions.

Experiments of Lavoifier to determine the fpecies of alteration the air undergoes from refpiration.

In order to know the fpecies of alteration which happens in the air after having been breathed by animals, he introduced a guinea-pig under a glafs bell which contained 248 inches of oxygen gas. The glafs was placed over mercury, and the animal left it in an hour and a quarter.

To render the comparifon more eafy, he fuppofes the quantity of oxygen gas to have been a cubic foot, or 1728 cubic inches, and calculates the refults. When the animal was withdrawn from the glafs, the number of inches was reduced to 1672$\frac{1}{2}$, which makes a diminution of 55$\frac{1}{2}$ inches: there were found at the fame time 229$\frac{1}{2}$ inches of carbonic acid gas, as appeared by the introduction of cauftic alcali; the reft was pure vital air.

By converting these volumes into weight, the quantities of air under the glass will amount to

	oz.	drac.	grs.
Vital air	1	2	$1\frac{3}{4}$
Carbonic acid gas	0	2	15
Total	1	4	$16\frac{3}{4}$

Hence the air in this experiment, although diminished by about $\frac{1}{32}$d of it's volume, was increased in absolute weight; from which, according to this philosopher, it results,

1st. That air extracts something from the lungs during respiration.

2d. That the substance extracted, combining with vital air, forms carbonic acid gas; and since it is known that there is no other substance but carbon possessing this property, it follows, that by the process of respiration a real carbonaceous matter is extracted. But this increase of weight, which appears to be only 21.87 grs., is really much more considerable than at first appears credible; for in the above experiment only $229\frac{1}{2}$ inches of carbonic acid gas were formed. Now, after some very exact experiments, it has been found by Lavoisier that 100 parts of carbonic acid gas in weight are composed of 72 of vital air, and 28 of carbon: hence the 229.5 inches of carbonic acid gas obtained, contain

	grs.
Of vital air	11.484
Of carbon	4.466

The 11.484 grs. of vital air amount in cubic inches to $229\frac{2}{3}$: if, therefore, there was only sufficient vital air used to form the carbonic acid gas, the remaining quantity ought to be 1728—$229\frac{2}{3}$.

	$1498\frac{1}{3}$
There was found only	$1443\frac{2}{3}$
Consequently a deficit of	$54\frac{2}{3}$

Hence, according to Lavoifier, independently of the vital air converted into carbonic acid gas, a portion of that which entered into the lungs did not return in an elaftic ftate; and therefore one of two things muft have happened during refpiration: a portion of the vital air either united with the blood, or combined with a portion of hydrogen gas to form water. Suppofing the laft, it is eafy after the above experiment, fays this chemift, to determine the quantity of water formed by refpiration, and the quantity of hydrogen gas extracted from the lungs. For fince, to form 100 parts of water, 85 parts of vital air in weight and 15 of hydrogen gas are employed, it follows, that with the 54 inches of vital air found wanting, 32.25 of water ought to be formed; and that there were $4\frac{1}{6}$ grains of hydrogen gas difengaged from the lungs of the above-mentioned animal. From this and other experiments he was led to conclude that refpiration only acts on the portion of oxygen gas contained in the atmofphere; that one portion is converted into carbonic acid gas, whilft the other is employed to form water.

His conclufion.

Compofition of the atmofphere.

According to Lavoifier, the atmofphere is compofed of 0.27 of pure air and 0 73 of azot; but it had long been fufpected by de la Metherie that fixed air likewife made a part of it, and Humboldt has fince proved he was right in his conjecture. He found that in it's ordinary quantity it amounts to 0.014, that it's maximum is 0.018, and it's minimum 0 005; and this quantity is fo ftrongly allied to the azot and oxygen as not to be feparated by the greateft portion of water the atmofphere contains. According to this chemift, it appears likewife, that it is not the quantity alone of oxygen contained in the atmofphere that renders it proper for refpiration, as in mines he found air which extinguifhed light and killed animals, that contained even 0.27 of oxygen.

Hence he affirms it is not the default of oxygen that

renders noxious atmofpheres or mofets fo mortal, but the manner in which this oxygen is combined. The atmofphere therefore is not a fimple mixture of 0.27 of oxygen, 0.72 of azot, and 0.01 of carbonic acid, but there is a real combination of all thefe principles united to the aqueous portion: he found that the oxygen the atmofphere contains varied from 0.23 to 0.29.

It appears there was no experiment of importance to determine the quantity of air the lungs contain, until that made by Borelli in the middle of the laft century. Having breathed through a glafs tube of which the volume was afcertained, and of which one end was immerfed in fome bubbles of foap, he found the quantity of air received into the lungs in one infpiration to be about 15 cubic inches; and towards the end of the experiment to be between 18 and 20 cubic inches. This experiment however is liable to objection; for it is, according to Menzies, not only inaccurate, from the friction and other caufes, but it is only the meafure of one infpiration.

Experiments to determine the quantity of air the lungs contain.

The next author is the celebrated Jurin. He fufpended a weight to the lower part of a bladder, previoufly moiftened; and having fixed a tube of about an inch diameter in the upper part, he ftopped his noftrils and infpired the air of the bladder gently, during three minutes, the weight remaining all the while on the table. He then plunged the bladder, with the air enclofed in it, and the weight fufpended to it, into water contained in a cylindrical veffel: he then marked the height to which the water rofe. Having now fqueezed the air out of the bladder, he again plunged it into the water with the weight. The difference of the height to which the water rofe in both thefe cafes was eafily calculated. Having repeated the experiment ten times, and added the quantities together, the tenth part of the fum total, or the proportional difference of the height to which the water rofe

Jurin.

in both cafes, was found equal to 35 cubic inches, which is the volume of air contained in the bladder ; and having added about the twelfth part, or three inches, on account of the condenfation of the air from the coldnefs of the water, as it was winter, it amounted to 38 cubic inches. He added a little, both on account of the preffure of the water on the bladder, and of the moifture which is expelled with the air, and foon condenfed by the coldnefs of the water and of the bladder. He then calculated the quantity of air, expelled by a moderate expiration in the fpace of three minutes, at 40 cubic inches. In the ftrongeft expiration he expelled 125 cubic inches in the fpace of a minute; but in a ftrong expiration, continued nearly until fuffocation, he expelled 220 cubic inches from the lungs. Hence it follows that there is more air in the lungs than can be expelled by an ordinary expiration.

This experiment proves that the quantity of air ufually expired is equal to 40 cubic inches. The accurate Hales, Haller, and Sauvages, who have repeated thefe experiments, have agreed that the refult was the fame. But according to Menzies, as it is only the meafure of one infpiration, it lies open to the fame objection as the former.

Hales, &c.

Dr. Goodwin.

This was alfo attempted by Dr. Goodwin. He endeavoured to breathe from a veffel full of air, joined by means of a tube to another full of water, fo that a certain volume of water, equal to that of the air infpired, might get into the place of the latter after each refpiration ; for the volume of water, fubftituted to that of the air infpired, muft be equal to that of the air confumed in infpiring.

Having contrived an apparatus for this purpofe, an adult of a middle fize, and in good health, endeavoured to refpire as naturally as poffible from this pneumatic veffel, and the

First time, he infpired 3 cubic inches ;

Second time, ... $2\frac{1}{2}$

Another perfon of the fame ftature endeavoured to breathe out of the veffel.

At the firft infpiration, he breathed $3\frac{1}{5}$ cubic inches;
At the fecond, ... $2\frac{3}{4}$.

But as the difference of the refult of both thefe experiments might be fuppofed to proceed from the different degree of attention, he varied the experiment in this manner. The fame man infpired and expired thirty times out of the fame veffel, and as nearly as poffible with the fame degree of exertion; and on calculation the average quantity of air of each refpiration was found to be $2\frac{3}{4}$ cubic inches.

Having repeated the fame experiment with the greateft care, the average quantity of each refpiration was found to be 3 cubic inches.

Another man of the fame ftature breathed 30 times from the fame veffel, and in the fame manner, and the average was $3\frac{1}{4}$ cubic inches. Hence it follows that the greateft quantity of air received into the lungs during each natural refpiration does not exceed $3\frac{1}{6}$ cubic inches; which is much lefs than what Hales and Jurin had calculated.

In the laft differtation of Dr. Goodwin, it appears that a dull kind of pain was felt in the cheft before the man had finifhed the number of infpirations. Having removed the tube from his mouth, it was neceffary to make a deep infpiration; which appears to Menzies to prove, that the quantity of air received into the lungs was not fufficient for the purpofes of refpiration. This defect however is attributed by the author to the imitation of natural refpiration, which could not counterbalance the difficulty of raifing water contrary to it's natural gravity. As an attempt to breathe in the open air would not give the meafure of an ordinary infpiration from the machine, it was neceffary to affift the action of the lungs,

by which the quantity received was much increaſed; as is evident from the following experiment, in which three perſons of ordinary ſtature inſpired from the machine 30 times ſucceſſively, and took in as much air at each time as the ſenſations in the breaſt ſeemed to require. The average quantity of air taken into the lungs at a ſingle inſpiration

By the firſt, was 12 cubic inches.
ſecond, . . 14
third, . . 11

Thus Dr. Goodwin concludes the quantity of air inſpired to be equal to 12 cubic inches, which are dilated by heat to 14; and as the quantity of air remaining in the lungs, after an ordinary expiration, is near 109 cubic inches, he concludes, the proportion of the dilatation of the lungs, before and after a healthy inſpiration, to be as 109 to 123.

Menzies. Dr. Menzies, who is the laſt that has made any experiments of this nature, although he is of opinion that Dr. Goodwin has come very near the point, yet in the different experiments on the ſubject he found no confidence could be placed in the method he employed, on account of the inaccuracies it was liable to; and he freely confeſſes it was by chance he firſt diſcovered them. The method which Dr. Menzies uſed ſeems to be ſimilar to that indicated by Boerhaave.

It conſiſts in being placed up to the neck in water, and judging of the dilation of the lungs from the aſcent and deſcent of the water. Dr. Menzies therefore procured a hogſhead, the top of which had an opening ſufficiently large for the head to paſs out; and a cylinder was fitted about his neck up to the chin, by which the riſing and falling of the water during reſpiration might be calculated.

1ſt Experiment. A healthy man, five feet eight inches high, was ſhut

up in this hogſhead, which was filled with water heated to 90° of Fahrenheit, as far as that part of the neck that was beſt ſuited to meaſure the difference of aſcent and deſcent. This difference was about 1.25 inches. His pulſe before and after immerſion beat 64 or 65, and his reſpirations were 14 or $14\frac{1}{2}$ in a minute, and they continued the ſame all the time he remained, which was two hours and upwards, during which the aſcent and deſcent of the water were $1\frac{25}{100}$ inch at leaſt: but when he made a deep inſpiration, ſo much air ruſhed into the lungs that the water paſſed out through the cylinder; but as the area of the cylinder was 55.41 ſquare inches, and the area of the neck 18; $55.41-18\times1.25=46.76$ cubic inches, the quantity of air uſually reſpired by this man. This was thrice repeated with the ſame reſult; but to prevent miſtake he was made to breathe through an allantoid.

This allantoid contained 2700 cubic inches, which in many trials he filled with 58 expirations, giving 46.55 cubic inches as the quantity of air expired; and this calculation is very near the preceding one. But as the reſpirations of this man appeared to be never more than 14 and $14\frac{1}{2}$ in a minute, it was probable he inſpired more air than other men of the ſame ſtature. To aſcertain this, and to be able to eſtimate the average quantity of air inſpired, it was neceſſary to examine the reſpiration of a man of ſmall ſtature.

2d Experiment.

Another man, therefore, only five feet and an inch high, was ſhut in the ſame hogſhead; the pulſe beat 72, and the number of reſpirations was 18 in a minute. The water was heated between the 85th and the 90th of Fahrenheit. The difference between the aſcent and deſcent during the long time he remained was 0.95 of an inch, or in vulgar fractions $\frac{95}{100}$ of an inch. The area of the cylinder was equal to 57.012 inches, and the area of the

neck to 14.0837 inches. Hence 57.012—14.0837 ×0.95 =40.781 cubic inches, is the quantity of air taken into the lungs by a common refpiration. This was confirmed by his breathing into the allantoid, which gave from 38 to 40 cubic inches, the meafure of a common infpiration. So that, if half the quantities of the two experiments be taken, there will be 43.77 cubic inches, the average quantity of air refpired. The afcent and defcent of the water were carefully marked by means of a glafs tube inferted into the top of the hogfhead, on which a fcale of degrees was cut; and on account of the attraction between the water and the fides of the tube $\frac{1}{20}$ was fubtracted; and if on account of the dilatation of the air by the heat of the lungs $\frac{1}{472.5}$ for every degree of heat be fubtracted, the quantity of air infpired may ftill be computed at 40 cubic inches.

Dr. Goodwin fuppofes that only 109 cubic inches remain in the lungs after an ordinary expiration, and that the proportion of their dilation after an ordinary expiration is to that of their dilatation after an ordinary infpiration as 109 to 123; but Dr. Menzies has remarked, that after an ordinary expiration a man could ftill expel 70 cubic inches of air from the lungs. Hence after fuch an expiration only 39 cubic inches of air will remain. "Without doubt then," fays Dr. Menzies, "as appears "from another experiment (Goodwin's Connexion of "Life with Infpiration, p. 46), Dr. Goodwin fuppofes "that 109 cubic inches of air remain in the lungs after "an extraordinary expiration: but as we have found "70 cubic inches to be the difference between an ordi-"nary and an extraordinary expiration, this number "added to the former, or to 109, will give 179, as the "quantity of air remaining in the lungs after an ordi-"nary expiration. Now the former experiments "fhow, that the quantity of air expelled by an ordinary

"expiration is equal to 40 cubic inches: consequently, "if this be added to 179, we shall have 219 cubic inches "as the quantity of air contained in the lungs before "expiration: hence the dilatation of the lungs before and "after an ordinary expiration will be as 219 to 179: or, "in other words, the thorax will be increased by a "quantity of air nearly equal to a cube of $3\frac{1}{2}$ inches; "which, if we consider how much the thorax and abdo-"men are dilated by an extraordinary inspiration, seems "very trifling. The difference between an extraordinary "expiration, or one made with some effort, and an extra-"ordinary inspiration, I have found to exceed 200 cubic "inches."

Dr. Goodwin's experiments to ascertain the degrees of change the parts of the atmosphere undergo in respiration.

As the atmospheric air undergoes a change by respiration in the proportion of it's constituent parts, the dephlogisticated air being diminished, the fixed air increased, whilst the phlogisticated remains the same; Dr. Goodwin was desirous of ascertaining the particular degree of these changes: he therefore began by finding the proportion of the airs in 12 cubic inches of atmospheric air; which being done, he inspired an equal volume of the same air, and then expired it into a glass receiver, and analysed the whole quantity. This having been repeated several times, the medium was as follows:

	Parts.		Parts.
The volume of air taken into the lungs at a single inspiration contained of phlogisticated air - - -	80	The volume of air expelled from the lungs by the next succeeding expiration contained of phlogisticated air - -	80
Dephlogisticated air - -	18	Dephlogisticated air - -	5
Fixed air - - -	2	Fixed air - - - -	13
	100		98

He found this diminution of the dephlogisticated air was sometimes $\frac{1}{10}$th or $\frac{1}{80}$th part.

He then attempted to find if this diminution of the one and increafe of the other be conftant and uniform in the fame volume of air feveral times refpired; for which purpofe, he firft examined the diminution of the dephlogifticated air, by breathing a quantity of air feveral times from a glafs receiver inverted in water; and by mixing a fmall quantity of this fame air, after every expiration, with an equal quantity of nitrous air in Fontana's eudiometer, in which the quantity of dephlogifticated air would be indicated by the diminution of volume in the eudiometer: he therefore paffed 12 cubic inches of atmofpheric air into a glafs receiver inverted in water, and put a meafure of it into this inftrument, where it occupied 100 parts: he then added an equal meafure of nitrous air, and the whole volume of 200 parts was diminifhed to - - - - - - - - 144

Then he infpired the whole of the volume from the receiver, and expired it in the ufual time; and on trying an equal portion of it in the inftrument, the 200 parts were diminifhed to - - 158

After the fecond expiration, to - - 163

After the third, to - - - 167

After the fourth, to - - - 170

After the fifth, to - - - 171

2dly. To determine whether the addition or increafe of the fixed air be uniform and conftant in feveral fucceffive refpirations, he enclofed 12 cubic inches of air in an inverted receiver, and breathed it through a glafs tube fix times in fucceffion; when, on being examined with lime water after the laft expiration, it contained 15 parts of fixed air: on repeating the experiment, the quantity of fixed air was 13 parts: hence the diminution of the dephlogifticated and the increafe of the fixed air is conftant and fucceffive in the fame quantity of air frequently breathed; but the changes in the fucceffive refpirations

bear no proportion to the changes in the firſt. Dr. Goodwin, finding therefore theſe changes ſo conſtant and uniform, ſuſpected they muſt be connected with ſome correſponding changes in the lungs, equally conſtant and uniform, which he found to be in the blood.

Count Morozzo, in order to prove the length of time different animals were able to live in different airs, ſo as to be able to form a compariſon, made the following experiments :

The oxygen gas he uſed was extracted from red precipitate and nitre, which he found to be of equal purity: the animals were ſparrows and rabbits, of an adult ſtate, that he might be able to compare the reſults, having obſerved that animals lived a longer or a ſhorter ſpace of time in a vitiated air according to their age; which difference ceaſes on their arrival at maturity. He uſed the method employed by Dr. Cigna of expoſing a ſucceſſion of animals to the ſame gas, and found the reſults to be perfectly ſimilar : he found that,

Experiments of Morozzo, on expoſing animals to different ſpecies of air.

		Hours.	Min.
In atmoſpheric air, the	1ſt ſparrow lived about -	3	—
	2d - - - -	—	3
	3d - ſcarcely -	—	1
In dephlogiſticated air, the	1ſt ſparrow lived - - -	5	23
	2d - - - -	2	10
	3d - - - -	1	30
	4th - - - -	1	10
	5th - - -	—	30
	6th - - - -	—	47
	7th - - - -	—	27
	8th - - -	—	30
	9th - - - -	—	22
	10th - - - -	—	21

On repeating his experiments in veſſels of equal ſize, he found that animals lived four and even five times longer in dephlogiſticated than in common air ; that after

the death of the animal a lighted candle was immediately extinguifhed in the atmofpherical air, but preferved it's brilliancy and vivacity in the dephlogifticated air, as if it had undergone no change; which is contrary to what Dr. Cigna obferved, that common air when vitiated by refpiration extinguifhes flame a long time before animal life. He remarks with Dr. Prieftley, that animals appear to be more gay and active in oxygen gas than in atmofpherical air; and that, when their refpiration appears troubled, they do not gafp for breath fo much, nor is their deatha ccompanied by fuch violent convulfions as in atmofpheric air; and that the duration of their life in oxygen gas did not decreafe in any marked proportion from the introduction of the fifth.

Having obferved that oxygen gas, in which different animals have fucceffively died, is ftill in a ftate of fupporting animal life a confiderable time, and flame with great vivacity, he was defirous of anfwering the following queftions:

1. To find the duration of animal life in dephlogifticated air, in which a candle had been extinguifhed; and he found animals lived in it nearly as long as in pure oxygen gas.

2. To difcover whether a lighted candle would burn in the oxygen gas in which flame had been extinguifhed, and he found it would not. In equal capacities, flame exifted five minutes in oxygen gas, and only forty feconds in atmofpheric air.

In order to difcover the leaft variations, Morozzo ufed veffels of a larger capacity, containing forty pounds of water, and larger animals, fuch as rabbits; and he found that,

		H.M.		Inch.Lin
In atmofpheric air, the	1ft lived	4 33,	and the abforption	0 9
	2d -	0 13,	- - - -	0 4
	3d -	0 5	- - - -	0

		H.M.	Inch. Lin.
In oxygen gas	1ſt	10 3,	2 0
	2d	3 57,	1 8
	3d	4 30,	2 2

He remarked with Dr. Prieſtley, that quadrupeds live longer than birds in vitiated air, from being accuſtomed to breathe nearer the ground, where the air is not ſo pure as in the higher regions; and he lays it down as a rule, that animals in oxygen gas conſume a quantity in proportion to common air as 5 to 1; which is the ſame proportion as that of the greateſt durability of their lives.

From expoſure of animals in different airs, he found,

Concluſions.

1. That the duration of animal life was in proportion to the greater quantity of oxygen gas the airs contained.

2. That in all where there was an equal part of oxygen gas, they lived conſiderably longer than in common air, except in the air vitiated by the vapour of charcoal, in which a ſparrow lived only 24 minutes, and in fixed air 38 minutes.

3. That in all thoſe of which one-third was oxygen gas, animal life was nearly equal to what it was in common air, except in the two laſt caſes.

4. Gaſes and infectious airs appear to be fatal in the order following:

Inflammable gas of marſhes - - - Air vitiated by vapour of ſulphur - -	nearly equal.
———by burning charcoal - - ———by a mixture of iron filings and moiſtened ſulphur - - - - Inflammable gas from iron and vitriolic acid Fixed air - - - - - - - - Air vitiated by animal reſpiration - -	nearly equal.

Prieſtley's experiments on animals in noxious airs.

Dr. Prieſtley has likewiſe made ſome experiments on animals in noxious airs; from which he found that animals, on being put into air in which other animals have died,

almoft always die in convulfions: they are sometimes affected fo fuddenly as to be irrecoverable after a fingle infpiration, although withdrawn immediately, and every care taken to recover them. They are affected in the fame way in every other noxious air; fuch as fixed air, inflammable air, air filled with fumes of fulphur, infected with putrid matter, in which a mixture of iron filings and fulphur has ftood, or in which charcoal has been burned, or metals calcined, or in nitrous air. According to Dr. Prieftley, animals become habituated by degrees to the noxious air; for he frequently found, that when a number of mice had been confined in a given quantity of air, a frefh moufe being introduced to them has been inftantly thrown into convulfions, and died. It is evident, therefore, that if the experiment of the black hole at Calcutta were to be repeated, a man would ftand the better chance of furviving it who fhould enter at the firft than at the laft hour. Dr. Prieftley has alfo obferved, that young mice will live much longer than old ones, or than thofe which are full grown, when they are confined in the fame quantity of air. He has known a young moufe to live fix hours in the fame circumftances in which an old moufe has not lived one: hence the uncertainty in making experiments of this kind, where a frequent repetition is neceffary to depend upon them.

Having given fome account of the ancient and modern opinions of refpiration in general, of the experiments that have been made on the effects of refpiration upon air, of the changes it fuffers from this procefs, of the formation of new fubftances found in expired air, of their proportions, of the opinions of feveral chemical phyfiologifts upon the quantity of air the lungs contain, and of the experiments made upon animals in different fpecies of airs, the next part of the fubject relates to the colour the blood receives during the refpiratory procefs, beginning with

ſome account of the opinions of different philoſophers upon this ſubject.

Colour of the Blood.—The ancients muſt undoubtedly have obſerved, that the ſurface of blood, after having been drawn from the body and left to repoſe, changed from a dark to a florid red colour, and that underneath it remained black; but they could have had no juſt idea of the cauſe of this change. It appears, that, among the moderns, Mayow was the firſt whoſe conjectures were conformable to the lateſt experiments. He ſays, that the fluid red colour of the blood is produced by the introduction of the nitroaerial ſpirit from the atmoſphere; for where the blood is not expoſed to this, it is black. As, however, this celebrated author's publication was ſcarcely known to exiſt previous to it's being introduced to public notice by Dr. Beddoes, nobody, unleſs we accept Lower, attempted to account for this difference, or the cauſe of the colour. Even ſo late as the time of Haller all was conjecture: this celebrated phyſiologiſt, on comparing the blood of an adult with that of the fœtus, which is deſtitute of the florid redneſs, only informs us that it was acquired in the lungs. The common opinion was, that the change of blood, on ſtanding, aroſe from it's containing two kinds of particles, red and black; and that the black, from their greater ſpecific gravity, fell to the bottom, whilſt the red particles remained at the ſurface.

Mayow.

Haller.

Cigna of Turin, at length, having paid great attention to this ſubject, publiſhed a memoir in the firſt volume of the *Miſcellanea Taurinenſia*, in which he very well accounts for this red colour of the blood, clearly proving it to be cauſed by the contact of air. He found, that, on covering the blood with a little oil ſo as to defend it from the atmoſphere, it remained black throughout; but when he took away the red part, and expoſed the lower *laminæ* to the air, which were black, they alſo became

Cigna.

fucceffively red, till the whole mafs had acquired this colour. At the requeft of Cigna, father Beccaria was induced to try the effect of expofing blood in the vacuum caufed by an air-pump, and he found that it always remained black, but became red on expofing it again to the atmofphere. Cigna concludes by obferving, that it is not eafy to account for the lower part of a mafs of blood becoming black, whether it arifes from the air it has imbibed efcaping from it, or from it's depofiting fomething faline, neceffary to contribute to it's rednefs, or from the preffure of the atmofphere; but he feems to think, that air mixed with blood, and interpofed between the globules, preferves it's rednefs; but that by concreting it is expelled from it, or becomes fo fixed as to be incapable of making it red. This opinion, he imagines, is rendered in fome meafure probable, by the increafed denfity of concreted blood, and by the emiffion of air from other fluids in a concrefcent ftate. In another memoir, he doubts whether the change of colour in the blood takes place in the lungs, but if it does, he is inclined to afcribe it to the *evaporation* from the blood in the lungs; and though he always found the colour of the blood was changed by the contact of air, yet when he confidered that evaporation muft neceffarily attend the contact of air, he fuppofed that this effect might equally be attributed to it. But he acknowledges confirmation by experiments is neceffary to this hypothefis.

Hewfon. Other experiments were made by Hewfon. He found that a folution of nitre changed dark-coloured blood to the moft beautiful red; but is of opinion that this cannot arife in the lungs, fince the air contains no nitre; and he found moft of the neutral falts in fome meafure produced the fame effect. He was certain, however, that, as the colour of the blood is changed by air out of the body, the air is the immediate caufe of the fame change in the body; and this change in the venous and arterial blood is pro-

duced in the lungs, he affirms, from experiments in which he diftinctly faw the blood of a more florid red in the left auricle of the heart than in the right; but how the effect is produced he thinks is undetermined.

Dr. Prieftley. The caufe of this change was determined by Dr. Prieftley; but he attempts to explain it according to the phlogiftic fyftem. He endeavoured to find whether blood was of fuch a nature as to retain the power of phlogifticating air when congealed, and out of the body, that it has when fluid and in the body; and the experiment anfwered his expectation. Having taken the blood of a fheep, and let it ftand till it was coagulated, and the ferum feparated from it, he introduced pieces of the craffamentum, contained in nets of open gauze or of wire, fometimes through water, and fometimes through quickfilver, into different kinds of air, and always found that the blackeft parts affumed a florid red colour in common air, and more particularly in dephlogifticated air, and in lefs time; whereas the brighteft red blood became prefently black in any kind of air unfit for refpiration, fuch as fixed, inflammable, nitrous, or phlogifticated airs; and after becoming black in the laft of thefe kinds of airs, it regained it's red colour on being again expofed to common or dephlogifticated airs; the fame pieces becoming alternately black and red by being transferred from phlogifticated to dephlogifticated air, and *vice verfa.*

In thefe experiments, Dr. Prieftley is of opinion, that the blood lofes it's black colour by giving it's phlogifton, which is the caufe of it, to the air; and that it receives it again on being expofed to the other airs containing this principle. He thinks that the blacknefs of the blood may arife from other caufes than it's acquiring phlogifton, as in vacuo; and fuch he found to be the cafe when it was covered two inches and a half with ferum, but regained it's florid colour again on expofure to the open air. He expofed

pieces of the fame mafs to nitrous and inflammable as well as fixed airs; they all became black, but that in the inflammable the leaft fo; but none of them recovered their fluid colour in the open air; one, however, in fixed air, recovered it in dephlogifticated air. The deeper the colour, the more the phlogifton it contains, and *vice verfa*. As it might be objected to this hypothefis of Dr. Prieftley, that the blood never comes into actual contact with the air in the lungs, but is feparated from it; and that the red globules alfo fwim in a large quantity of ferum, a fluid of a quite different nature; in order to afcertain the effect of thefe circumftances, he took a large quantity of black blood, and put it into a bladder moiftened with a little ferum, and, tying it very clofe, hung it in a free expofure to the air, though in a quiefcent ftate; and the next day he found that all the lower furface of the blood feparated from the common air by the bladder (which is an animal membrane like the veficles of the lungs, and at leaft as thick), and likewife a little ferum, had acquired a coating of a florid red colour, and as thick as if it had been immediately expofed to the open air; fo that the membrane had been no impediment to the action of the air on the blood. He repeated the experiment without previoufly moiftening the bladder, and with the fame refult. He found that a piece of the craffamentum acquired the florid colour even when covered with ferum to the depth of feveral inches; but, that the flighteft covering of water or faliva effectually prevented it's acquiring this colour, which proves how wonderfully well the ferum is adapted as a vehicle for the red globules. To fatisfy himfelf completely that it is really the air acting through the ferum, and not the ferum itfelf that gives the florid colour, he took two equal portions of black blood, and put them into equal cups, containing equal quantities of ferum, which covered them to the depth of half an inch. One of thefe

cups he expofed to the air, and the other under an exhaufted receiver, when the former prefently acquired a florid colour, and the other continued twelve hours as black as the firft. It alfo remained black when expofed to the air, and the ferum taken off. He reverfed this experiment, and found that red blood became black through the depth of two inches of ferum, expofed to phlogifticated air; a confirmation that the red globules of the blood receive and part with phlogifton by means of the air, notwithftanding the interpofition of a large body of the fluid in which they naturally float.

Dr. Prieftley, however, does not infer, in all cafes, that blood becomes black by imbibing phlogifton *ab extra*; for, if time be given it, this change may arife from *internal caufes*, as from putrefaction, which he found by experience.

Except ferum, he found that milk is the only animal fluid through which the air can act upon blood, for black blood became red when plunged into milk as if covered with ferum. It becomes inftantly red in urine, which he attributes to the faline nature of that fluid. This makes it probable, that the rednefs of the blood is owing not only to it's *parting* with phlogifton, but to *imbibing* the acidifying principle from the dephlogifticated air.

As the principal ufe of the blood appears to Dr. Prieftley to be derived from it's power of receiving and difcharging phlogifton, and the degree in which it poffeffes this power is eafily afcertained by the eye, it might, he thinks, be worthy the attention of phyficians; for in cafes in which the blood is unufually black, and but little affected by common air, perhaps breathing a purer air might be prefcribed with advantage. In general, the blood he procured in the city was not fo good as that got in the country, which he attributes to the cattle having been much driven and heated before they were killed.

It appears from Dr. Prieſtley's account, that having afterwards made ſome experiments on the mutual tranſmiſſion of dephlogiſticated air, and of inflammable and nitrous, through a moiſt bladder interpoſed between them, and from the opinions of others, he was ſoon convinced, that, beſides the emiſſion of phlogiſton from the blood, dephlogiſticated air, or the acidifying principle of it, is at the ſame time received into the blood; yet he appears ſtill to be of opinion, that although the application of dephlogiſticated air to the outſide of a vein may change the colour in it, as Dr. Goodwyn has proved, this might have been affected, as he firſt ſuppoſed, by the ſimple diſcharge of phlogiſton from the blood, when it had an opportunity of uniting with the dephlogiſticated air thus preſented to it.

Lavoiſier and Crawford.

Lavoiſier and Crawford formed their opinion of the colour of the blood from the experiments which Prieſtley and Hamilton made. The laſt made three ligatures upon the jugular vein of a cat; having extracted the blood comprehended between two of theſe ligatures, he introduced hydrogen gas into it, and detained it by cloſing the oriſice; he then united the middle ligature, and the blood between the third ligature and that of the middle became in contact with the hydrogen gas. Having drawn the blood from the vein, he found it liquid, and that it had acquired a colour nearly as deep as ink. Venous blood expoſed to vital air acquires the vermilion colour of arterial blood, and the vital air is vitiated. From theſe experiments, Lavoiſier and Crawford are of opinion, that the change of colour the blood undergoes in the courſe of circulation proceeds from it's uniting with hydrogen; that the blood when it paſſes through the lungs communicates a part of it's hydrogen to the oxygen contained in the inſpired air, and that it then receives it's red colour again.

Dr. Goodwyn

It had long been obſerved by Lower (Tract. de Corde, p. 185.), in living animals, that the blood from a wound

in the trunk of the pulmonary vein was florid; and knowing before that the blood entering the lungs by the pulmonary artery is black, he concluded that it acquired this florid colour by paffing through the lungs; and finding afterwards, that when the animal ceafed to breathe, the blood from the wound in the pulmonary vein was black, he attributed the florid colour to the action of the air in refpiration. Dr. Goodwyn, ftruck with this fact, undertook to examine the truth of it. He procured fome large dogs, removed the fternum, and expofed the trunks of the pulmonary veins and arteries, fo as to be able to diftinguifh accurately the colour of the blood paffing through them. He then inflated the lungs with bellows, as defcribed by Vefalius, fo as to imitate the natural refpiration, and he kept the animal alive by this procefs a confiderable time. In thefe experiments he obferved, that, during the inflation, the blood in the trunks of the pulmonary artery was black, but in the trunks of the pulmonary veins florid; and when the inflation was intermitted for a minute, the blood in the trunks of the pulmonary vein became gradually black, like that in the arteries. Dr. Goodwyn likewife confirmed Lower's opinion by other experiments on the toad and lizard, whofe lungs confift of only a tranfparent bladder, with blood-veffels fo thin that the colour of the circulating blood may be eafily diftinguifhed through them; and in all the examples, when the air paffed into the lungs; the blood in the pulmonary veffels became gradually florid; but when they were emptied by preffure, it became gradually black.

Dr. Goodwyn then inquired to what part of the air refpired this change of colour was owing, whether to the addition of fixed air feparated from the blood in paffing through the lungs, or to the action of the phlogifticated or dephlogifticated air. He found by experiment, that

frefh drawn florid blood expofed to fixed air underwent no fenfible change, and as black blood frefh drawn undergoes no change of colour when expofed to dephlogifticated air, he tried what the change of venous black blood would be when expofed to dephlogifticated air, and found, in fupport of the common affertion, that it became florid, whilft a fmall portion of the air difappeared during the procefs; hence he is difpofed to believe, that when the dephlogifticated air produces this change, fomething at prefent unknown pervades the coats of the pulmonary veffels by the force of chemical attraction.

Dr. Goodwyn concludes that,

1. A quantity of dephlogifticated air is feparated from the atmofpheric air in the lungs.

2. That this dephlogifticated air exerts a chemical action upon the pulmonary blood, in confequence of which it acquires a florid colour.

Girtanner. If arterial blood be expofed to hydrogen gas in a glafs veffel, the quantity of gas is diminifhed, and the vermilion colour of the blood is change to a deep colour. In this experiment, according to Girtanner, the contrary paffes to what it does in refpiration. The hydrogen gas in the laft cafe unites to the oxygen of the arterial blood, to form water, and the arterial blood being deprived of oxygen becomes black, and is changed into venous blood, it's deep colour arifing from the lofs of it's oxygen. The experiment of Hamilton, before quoted, is explained by Girtanner in the fame way. In this cafe the blood was found liquid, and little coagulable, which Girtanner likewife reckons in his favour; for in his firft memoir he afferted, that the coagulability of the liquids followed the fame laws, and depended upon the fame principle, as the irritability of the folids, confequently the blood deprived of the irritable principle, or of the oxygen, ought to be liquid, *i. e.* little or not coagulable. This chemical phyfiologift,

after having ſhown that the arguments hitherto brought are not convincing, proceeds to bring proofs in favour of his own theory.

1. *Venous Blood.* Six ounces of black venous blood, drawn from the jugular vein of a ſheep, were expoſed to oxygen gas under a glaſs. It was inſtantly changed to a vermilion colour; the thermometer mounted a few degrees, and deſcended again. The mercury under the glaſs aroſe ſix or eight lines. The blood weighed a little more than before. This proves, according to Girtanner, that the blood during reſpiration abſorbs oxygen. This was confirmed by a ſecond experiment. He opened the jugular vein of a ſheep, and received the blood in a bottle filled with oxygen gas, and the bottle when half full was ſtopped. The blood immediately became of a vermilion colour, very fluid, and only coagulated ſlowly into a thick and reddiſh maſs, from which no ſerum was ſeparated.

He injected a pretty conſiderable quantity of very pure oxygen gas into the jugular vein of a dog, which killed it in leſs than three minutes. He found the heart more irritable than ordinary. The right auricle and ventricle contained blood of a vermilion colour not coagulated. The blood in the left ventricle, the aörta, and the arteries, was of a roſe-colour, and mixed with blebs of air. This proves that the vermilion colour is not owing to the loſs of carbonated hydrogenous gas in reſpiration, but to the blood combining with the oxygen gas. In this experiment, the deep colour of the venous blood of the right auricle and ventricle was changed into a vermilion; yet there could be no loſs of carbonated hydrogenous gas; there was only an addition of oxygen gas.

He injected a ſmall quantity of azot gas, deprived of fixed air by lime-water, into the jugular vein of a dog, which died in twenty ſeconds. The blood of the right auricle and ventricle was black, thick, and coagulated.

The left ventricle was of it's ordinary colour. He found that the venous blood of a ſheep expoſed to azot became black nearly as ink, and coagulated immediately; that a quantity of ſerum was ſeparated, and the following day a ſlight odour of ammonia was perceived on opening the bottle.

This proves that the colour of the blood ariſes from the azot; and the ammonia from the union of the ſame azot with the hydrogen gas of the venous blood. The colour of the blood becoming more deep after having loſt a part of it's hydrogen, appears to prove that this deep colour is owing to the carbon of the blood, and not to the combination of the hydrogen gas, as is thought. The venous blood of a ſheep expoſed to carbonic acid gas in a bottle immediately coagulated, became of a very deep colour, and a great quantity of reddiſh ſerum ſeparated. A ſmall quantity of carbonic acid gas being injected into the jugular vein of a dog, killed it in a quarter of an hour. The blood of the right auricle and ventricle was thick, and in part coagulated; that of the left was of a much deeper colour than uſual. This likewiſe proves that the deep colour of the venous blood is not owing to the combination of hydrogen gas. One part of the oxygen of the carbonic acid gas probably united to the hydrogen of the blood to form water, and the carbon previouſly united to this oxygen combined with the blood, and gave it a deeper colour.

The venous blood of a ſheep being expoſed to nitrous gas, immediately coagulated, and a great deal of blackiſh ſerum ſeparated. The next day, on opening the bottle, a very ſtrong odour of nitric æther (dulcified ſpirit of nitre) was perceived, the nitrous gas having been in part changed into nitric æther by the carbonated hydrogen of the venous blood; which proves that the venous blood contains carbonated hydrogenous gas, which is eaſily ſe-

parated. The blood having loſt this gas, had not received it's vermilion colour; but, on the contrary, a deeper colour. The deep colour of the venous blood is not, therefore, owing to it's union with carbonated hydrogen, ſince it becomes deeper after the ſeparation of the hydrogen.

A ſmall quantity of nitrous gas injected into the jugular vein of a dog, killed it in leſs than ſix minutes. The blood in the right auricle and ventricle was black, thick, and in part coagulated: that in the left was much more deep than uſual.

2. *Arterial blood.*—Some arterial blood, from the carotid artery of a ſheep, was expoſed to oxygen gas in the ſame way as the former experiments were made, and it immediately received a more vermilion colour. The day after, a very ſmall quantity of carbonic acid gas was found mixed with the oxygen gas.

Arterial blood immediately coagulated with azot gas, and became of a very deep colour. The day after, a ſmall quantity of oxygen gas was found mixed with the azot gas, ſo that a candle burned in it nearly two minutes. This experiment proves, 1. that arterial blood contains oxygen gas: 2. that it's vermilion colour is owing to it's union with this gas; and that, as ſoon as it is deprived of it, it aſſumes it's deep colour again.

The blood expoſed to carbonic acid gas received no effect from it, although it has a great effect on venous blood. Expoſed to nitrous gas, it immediately coagulated; and it's ſurface was green, and a little greeniſh ſerum ſeparated. The day after, vapours of nitrous acid were obſerved on opening the bottle. This likewiſe proves the preſence of oxygen in the blood, by it's converting the nitrous gas into nitrous acid; the green was owing to a ſmall portion of azot, which ſeparated from the nitrous acid. Expoſed to hydrogen gas, it became

more vermilion-coloured, and remained fluid ſome time before it coagulated, when a little ſerum ſeparated. The next day a little oxygen gas was found with the hydrogen gas; this alſo, according to Girtanner, proves the preſence of oxygen gas in the arterial blood.

A ſmall glaſs tube filled with arterial blood, and ſealed hermetically, was expoſed to the light; it's colour changed by degrees; and, in ſix days, it was as black as venous blood. This repeated, but expoſed to heat inſtead of light, the blood became black in a much leſs time. Theſe two laſt experiments, firſt made by Dr. Prieſtley, appear to Girtanner to prove it is not to the contact of hydrogen gas that venous blood owes it's black colour. From theſe experiments Girtanner concludes that,

1. The change of colour in the blood, during circulation, is not owing to it's combination with hydrogen gas.

2. That the vermilion colour of arterial blood ariſes from oxygen, with which the blood combines during it's paſſage through the lungs.

3. That the deep colour of the venous blood is owing to the carbon it contains.

Haſſenfratz. Haſſenfratz agrees pretty much with Girtanner. His opinion is, that the red colour of the blood proceeds from the ſolution of oxygen gas, and that it's brown and even black colour is occaſioned by union of the hydrogen and carbon with the oxygen it holds in ſolution. He draws his concluſion from theſe facts. He firſt ſtates the two facts upon which all chemiſts are of accord—1. that venous blood, mixed with oxygen, immediately receives a beautiful vermilion colour; that this red colour changes, by degrees, and becomes of a purple, like the ley of red wine, although the blood has been continually in contact with the oxygen, and both air and blood be conſtantly ſhaken together in order to unite them. 2. That arterial

blood, expofed to the action of every gas which does not contain oxygen, receives a colour of the ley of wine. From thefe he infers, that the red colour proceeds from the folution of oxygen in the blood, and it's purple colour from the oxygen abandoning the blood, and uniting with it's hydrogen and carbon. The experiments Haffenfratz made to convince himfelf of this are, he found that oxygenated muriatic acid, when added to venous blood, immediately decompofed it, and gave it a deep and almoft black colour. He poured the fame quantity of common muriatic acid into the quantity of blood, and the blood was immediately decompofed, and flocks of a clear brown were precipitated, that had not the black colour it took with the oxygenated muriatic acid. Since the difference between the oxygen of the oxygenated muriatic acid and oxygen gas is, that the firft is in a ftate fo as immediately to combine on being put into contact with the hydrogen and carbon of the blood, whilft the fecond is in a ftate which renders the combination difficult, it follows, that the colour the blood fuddenly takes with the oxygenated muriatic acid, is that which blood ought to take, in length of time, with oxygenous gas. Thus the black colour of the blood is the refult of the intimate combination of the oxygenous gas with the carbon and hydrogen of the blood, whilft it's red colour is only the refult of the folution of oxygen gas in the blood. To affure himfelf more pofitively of this truth, he repeated an experiment of Girtanner: he filled feveral glafs tubes full of blood made red by oxygen gas, and fealed them hermetically; fome of which he put into the light, others into the dark, and he found that the blood in all was become blackifh, like the ley of wine. The reafon therefore of the two phenomena which have excited the curiofity of all philofophers, viz. the red colour of the blood in contact with oxygen, and the brown colour when in contact

with the other gafes, are eafily explained. As long as the blood is in contact with oxygen, and this gas is diffolved in the blood, it is of a beautiful red ; but when it is in contact with gafes that contain no oxygen, that which is diffolved in the blood, and which occafions it's vermilion colour, quits, by degrees, the whole mafs of blood to combine partially with it's hydrogen and carbon, and it's colour is brown ; and as the air in contact cannot furnifh new oxygen, the colour continues to darken until all the diffolved oxygen is combined. This chemift likewife explains the particular fact obferved by Fourcroy ; the diminution of the high red colour of the blood, conftantly in contact with hydrogen gas, by the diminution of the force of attraction of the blood toward the oxygen gas, in proportion as it's carbon and hydrogen are combined with the gas of which it was firft in poffeffion ; which affords a belief, that, fince the blood which circulates has always the fame property of becoming red by mixing with oxygen, although it has already taken a confiderable quantity, during it's circulation it takes from the fubftances with which it is in contact a quantity of hydrogen and carbon, equal to that which fucceffively combines with the oxygen. He then made fome obfervations on the hypothefis of de la Grange. He obferves, that fince the red colour of the blood is the confequence of the folution of oxygen gas in it ; fince the purple colour of the ley of wine, and even the dark brown colour, proceed from the union of oxygen gas with the carbon and hydrogen of the blood ; fince the venous blood is purple, and the arterial blood vermilion ; it follows, that the arterial blood contains oxygen gas in folution, that this oxygen unites itfelf by degrees with the hydrogen and carbon of the blood during it's circulation, and when the blood returns by the veins into the lungs all the combination is made, and that it there diffolves again

oxygen gas, to return with a vermilion colour into the arteries. As the dark brown colour of the blood is in confequence of the union of oxygen with the carbon and hydrogen of the blood, and as the blood on paffing from the veins into the lungs to return back into the arteries becomes vermilion, it follows, that in the lungs very little union takes place between the carbon and hydrogen of the blood with the oxygen of the infpired air, and that the greateft combination is made during the circulation. It follows, therefore, on concluding, according to Haffenfratz, that,

1ft. The red colour of the blood is the refult of it's diffolving oxygen gas.

2d. That it's brown and even black colour arife from the combination of the hydrogen and carbon of the blood with the oxygen diffolved in it.

According to Davy, the arterial blood owes it's fine vermilion colour to light and oxygen, or the phofoxygen entering into it's compofition; and the venous blood is black, from a deficiency of phofoxygen, and a fuperabundance of carbon. Having defcribed the principal experiments and opinions of chemifts on the caufe of the difference of colour between venous and arterial blood, the third part of this article of refpiration will give an account of the different fyftems on animal heat. Davy.

Animal Heat.—The origin and caufes of heat in the animal body have been fubjects of difcuffion from the earlieft ages; but the ignorance of the ancients in fcience, and their fuperftition, which is always the confequence of it, enabled them only to form extravagant and abfurd ideas. It is well known how greatly they were inclined to attribute every thing they could not underftand to fupernatural power, and this propenfity pervaded the wifeft. We are told that even the great father of medicine, Hippocrates, was not devoid of this weaknefs. He confidered heat as a myftery, and even beftowed upon it feveral of Opinions of it. Hippocrates.

the attributes of the Deity. "What we call heat," fays he, "appears to be fomething immortal." We learn from Galen that the hypothefis amongft fome phyficians in his time was, that animal heat depended on the motion of the heart and arteries; and as they looked upon this motion to be innate, they confidered that heat was likewife fo: this hypothefis however he rejects; and, being a peripatetic philofopher, he accounts for it according to that fyftem.

Galen.

Amongft the moderns, different authors have amufed themfelves and the world by inventing many fanciful theories on this fubject. Thus Van Helmont and Sylvius attributed animal heat to the effervefcence which they thought took place in the inteftinal canal from the mixture of the pancreatic juice and the bile. This notion appears to have originated from having obferved that a degree of heat was produced from the mixture of certain bodies, which fometimes amounted to actual inflammation. Others attributed it to the fame caufe; but difagreed as to the place where this mixture happened, and of the nature of the fluids of which it confifted.

Helmont.

Accounted for by mixture.

Another opinion, which continued nearly two centuries, was that of the mixture of acids and alkalis; it was imagined that acefcent fluids, when taken into the ftomach, met with others of an alkaline nature already prepared; and this gave rife to the heat peculiar to the animal body.

After the abfurdity of explaining the phenomena of the human machine by chemical mixture had been perceived by phyfiologifts, it was fucceeded by fermentation. It had been obferved that fermentation was productive of heat, and as it was the fafhion to explain the phenomena which took place in the vital functions by fermentation, they thought they could not do better than to attribute animal heat to the fame caufe; and although fome of them modified their conjecture refpecting the peculiar fpecies of

Fermentation.

fermentation, it was chiefly confined at laſt to the putrefactive, more eſpecially as it was ſuppoſed that proceſs took place during digeſtion. Soon after the immortal Harvey had explained the circulation of the blood, the mechanical generation of animal heat took it's riſe; and ſo certain were phyſiologiſts of it's truth, that they looked upon it almoſt as capable of mathematical demonſtration. They firſt conceived this opinion from obſerving that animal heat generally keeps pace with the ſtate of the circulation; that when the heart and arteries beat high and quick, a great degree of heat is produced: on the contrary, when their action becomes more faint and languid, the animal heat is likewiſe diminiſhed. There was, however, one point in which the mechanical phyſiologiſts could not agree, *i. e.* whether it were occaſioned by the attrition of the blood againſt the veſſels which contain it, or by the internal agitation and friction of the particles againſt each other. Hence it gave riſe to various conjectures: many ingenious arguments were brought in ſupport of each hypotheſis; but, as facts could not determine the point, it fell, as moſt other hypotheſes do, for want of proper evidence. Mechanical means.

According to Dr. Mortimer, animal heat ariſes from the phoſphorus and air which the animal fluids contain. He thinks theſe lie in a dormant ſtate until brought into contact, which is effected by means of the circulation; and if it were not for the abundance of aqueous humours in animals, he alleges that incenſions would frequently happen. Opinion of Dr. Mortimer.

According to Douglas, animal heat ariſes from the friction of the globules in their circulation through the capillary veſſels. Stevenſon ſays that it is owing to the ſame proceſs by which our aliment and fluids are perpetually made to undergo ſome alteration. According to Franklin, the fluid fire, as well as the fluid air, being at- According to Douglas.

tracted by plants in their growth, and consolidated with the other materials of which they are composed, after being digested, and having undergone a kind of fermentation in the vessels, part of the fire and air recovers it's fluid active state again, and diffuses itself over the body, which is the animal heat.

Cullen.

A more accurate and extensive knowledge of the human œconomy soon saw into the futility of such methods of argument, and a more ingenious hypothesis perhaps than had hitherto appeared was attempted by Dr. Cullen, which he delivered in the form of little more than a conjecture. He was of opinion that the difference of temperature in different animals is owing to a difference in the vital principle; so that, although the velocity of the blood may be the same in a frog as in a man, yet, in consequence of the variety in the vital principle, the heat produced may be different; hence he supposes the principle of life has the power of generating heat or cold.

The doctrine of Stahl in fashion. Opinion of Black.

The phlogiston of Stahl now came more into fashion, and served to explain the origin of animal heat. Dr. Black having observed that animals which respire are of all others the warmest, and that there exists a striking and close connexion between their state of respiration and their degree of heat, was induced to conclude that animal heat is generated in the lungs by the action of the air on the phlogiston or principle of inflammability, in a manner not dissimilar to what he supposed to take place in actual inflammation, and that it is diffused by the circulation over the rest of the system. This opinion was defended by many arguments.—1. It was said, that since a quantity of mephitic phlogisticated air is known constantly to exhale from the lungs, and that atmospheric air, by passing through the lungs, acquires the same properties as by passing through fuel in actual inflammation, or by being exposed to any other process of

phlogiſtication, it is obvious that the change the common air undergoes in both caſes ought to be attributed to one and the ſame cauſe, viz. it's combination with phlogiſton. 2. This hypotheſis has been ſupported by urging, that the celerity with which the principle of inflammability is ſeparated in reſpiration, is very cloſely connected with the degree of heat peculiar to each animal. Thus man, birds, and quadrupeds, vitiate air very faſt; ſerpents and all the amphibious ſpecies, very ſlowly; and the latter are of an inferior temperature to the former, and breathe leſs frequently. 3. The moſt ingenious and cogent argument which the defenders of this theory have uſed is, that no heat is generated till the function of reſpiration takes place; for the fœtus in utero derives all it's heat from the mother.

Oppoſed by Dr. Leſlie.

Againſt this theory, Dr. Leſlie brings the following objections. 1ſt. That there are various proofs of the impoſſibility of the lungs being the ſource or elaboratory of animal heat, ſince animals without organs of reſpiration generate heat, and even thoſe fiſhes which are deſtitute of gills appear, from various experiments, to be warmer than the ordinary temperature in which they live: hence reſpiration is not abſolutely neceſſary for the production of animal heat. 2. If animal heat be generated ſolely in the lungs, it can only be communicated to the reſt of the body by the arterial ſyſtem, and the heat muſt decreaſe as it recedes from it's ſuppoſed centre. But it is more conformable to facts, that the venous blood is, if not warmer, at leaſt as warm as the arterial; and according to Dr. Stevenſon the thermometer immerſed in flowing venous blood riſes ſeveral degrees higher than that placed in the arterial, whilſt there is no experiment to ſhow the temperature of the blood to be higher in the left ventricle than in the right; which would be the caſe if all the animal heat was generated in the lungs. 3. Having thus

rendered it improbable that the generation of animal heat ſhould be entirely confined to the lungs, Dr. Leſlie endeavours to ſhow that the vital fluid, far from acquiring all it's heat in the pulmonary ſyſtem, communicates no inconſiderable portion of what it has received in the courſe of circulation to the air, alternately entering and iſſuing from that organ. Were the blood heated in the lungs, their function would be leſs neceſſary in a warm than in a cold atmoſphere: but it is known that when the air is extremely hot a perſon breathes full and quick to become cool, and in intenſe cold reſpiration is ſlow and languid; which would not be the caſe if the blood was heated in the lungs by the action of the air upon it. The air appears rather to diminiſh than increaſe the animal heat by carrying off phlogiſton from the lungs: hence Dr. Duncan compared reſpiration to the blowing of bellows on a hot body; in both caſes a conſiderable degree of heat is communicated to the air. Dr. Leſlie having thus brought his arguments againſt the theory of Dr. Black, and after ſhowing that heat, though *generated*, cannot accumulate in the fœtus, erects another theory in it's place, which depends upon the following poſitions:

Opinion of Dr. Leſlie.

1. That the blood contains phlogiſton.

2. That this phlogiſton is evolved, extricated, or brought into a ſtate of activity and motion, by the action of the blood-veſſels to which it is ſubjected in the courſe of circulation.

3. That the evolution of phlogiſton is a cauſe which throughout nature produces heat; whether that heat be apparently excited by mixture, fermentation, percuſſion, friction, inflammation, ignition, or any ſimilar cauſe.

4. That this heat, produced in conſequence of the evolution of phlogiſton from the blood of different animals, is in all probability equal to the higheſt degree of heat theſe animals in any caſe poſſeſs. To this theory of

Dr. Leflie fucceeded that of Dr. Adair Crawford, who proved the fundamental principle Leflie laid down, viz. that the venous blood is warmer than the arterial, to be falfe. He likewife appears to be the firft who attempted to afcertain, by direct experiment, the caufe of animal heat.

Dr. Crawford, who in his general doctrine of heat feems to agree with Dr. Irwin of Glafgow, begins with an explanation of his terms. The words *heat* and *fire* he tells us are ambiguous. *Heat* in common language has a double fignification: it is ufed indifcriminately to exprefs a fenfation of the mind, and an unknown principle, whether we call it a *quality* or a *fubftance*, which is the exifting caufe of that fenfation. The latter, with Dr. Irwin, he calls *abfolute heat*, the other *relative heat*. It therefore appears that *abfolute heat* expreffes in the abftract that *power* or *element*, which, when it is prefent to a certain degree, excites in all animals the fenfation of heat; and *relative heat* expreffes the fame power, confidered as having a relation to the effects by which it is known and meafured; for inftance, fuch as the effect it produces upon an inftrument called a thermometer, employed in meafuring it. It has been found by experiment, that in bodies of different kinds the quantities of abfolute heat may be unequal, though the temperatures and weights, or their relative heat be the fame. Thus, if a pound of water and a pound of diaphoretic antimony have a common temperature, the quantity of abfolute heat contained in the former is nearly four times that contained in the latter. When the principle of heat is confidered relatively to the whole quantity of it contained in bodies of different kinds, but which have equal weights and temperatures, it is termed *comparative* heat. If, for example, the temperatures and weights being the fame, the whole quantity of heat in water be four times as great as that in an-

Theory of Crawford.

Heat.

Abfolute.

Relative.

Comparative.

timony, the comparative heats of thefe fubftances are faid to be to each other as four to one. The comparative heats of bodies of equal weights and temperatures are greater or lefs in proportion, as lefs or greater alterations are produced in their temperatures by equal quantities of abfolute heat. Thus, the fame quantity of heat which raifes a pound of water one degree is fufficient to raife a pound of mercury 28 degrees: hence the comparative heat of water is to that of mercury as 28 to 1. As equal weights of heterogeneous fubftances are found to contain unequal quantities of abfolute heat, there muft be certain effential differences in the nature of bodies, from which *fome* have the power of collecting and retaining that element in greater quantity than others. Thefe different powers are called the *capacities* of bodies for containing heat: thus, if a pound of water contains four times as much abfolute heat as a pound of diaphoretic antimony at the fame temperature, the capacity of water for containing heat is to that of antimony as four to one. Such are the principal definitions Dr. Crawford has laid down. He then gives fome general facts refpecting heat, and afterward begins to examine animal fubftances, fo as to produce a theory upon animal heat.

Capacities of bodies for containing heat.

On making experiments with animal fubftances refpecting their comparative heats, he found that arterial blood contained a greater quantity of abfolute heat than water, which compofed fo large a portion of it; for, taking water as a ftandard at 1.000, arterial blood was 1.03. The remarkable accumulation of heat in this laft fluid led Dr. Crawford to fufpect it abforbs heat from the air in the procefs of refpiration; and he was much confirmed in his fufpicion by the following confiderations:

Arterial blood contains more heat than water.

Confiderations in confequence.

1. Thofe animals furnifhed with lungs, and which continually infpire frefh air in large quantities, have a tem-

perature confiderably higher than the furrounding atmofphere, whilft animals without refpiratory organs are nearly of the fame temperature with the medium in which they live.

2. Among hot animals, thofe are warmeft which have the largeft refpiratory organs, and which confequently breathe the greateft quantity of air in proportion to their bulk, fuch as birds.

3. The degree of heat in the fame animal is in fome meafure proportionable to the quantity of air infpired in a given time: thus the animal heat is increafed by exercife, or whatever accelerates refpiration.

Propofitions from a particular examination of animal heat.

From thefe he was led to examine the fubject of animal heat more particularly, the refult of which is comprehended in the following propofitions:

1. The quantity of abfolute heat contained in pure air is diminifhed by the change it undergoes in the lungs of animals, and the quantity of heat in any kind of air fit for refpiration is nearly proportional to it's power in fupporting animal life.

2. The blood which paffes from the lungs to the heart by the pulmonary vein contains more abfolute heat than that which paffes from the heart to the lungs by the pulmonary artery.

3. The comparative quantities of heat in bodies fuppofed to contain phlogifton are increafed by the changes they undergo in the proceffes of calcination and combuftion.

4. The colour of the venous blood of a living animal approaches more nearly to that of the arterial in a warm than in a cold medium; lefs air is phlogifticated, in a given time, in the former than in the latter fituation; and the heat produced by the refpiration of an animal is nearly equal to that produced by the burning of wax or charcoal, the quantities of pure air confumed being the fame.

Explanation of animal heat from Dr. Crawford's experiments.

Dr. Crawford, from experiments made on the comparative heats of different airs and animal fubftances, fo as to explain the phenomena of refpiration and animal heat, found that water being the ftandard at 1.000, inflammable air was 21.4000; dephlogifticated air 4.7490; atmofpherical air 1.7900; aqueous vapour 1.5500; fixed air 1.0454; phlogifticated air 0.7936; arterial blood 1.0300; venous blood 0.8928; frefh milk of the cow 0.9999; hide of an ox with the hair 0.7870; lungs of a fheep 0.7690; lean of the beef of an ox 0.7400:—he therefore forms an eftimate of the quantity of heat yielded by the purer part of atmofpherical air when it is converted into fixed air and aqueous vapour during refpiration, and alfo of that which is abforbed during the converfion of venous into arterial blood by the fame procefs, explaining his theory of animal heat in the following manner.

From having proved that the comparative heat of pure air is to that of the fixed air and aqueous vapour, into which it is changed in the lungs, as three to one, the fame heat which raifes the pure air one degree will raife the fixed air and aqueous vapour three degrees; and, confequently, the fame heat which raifes pure air any given number of degrees will raife the fixed air and aqueous vapour the fame number of degrees multiplied by three.

Having proved that pure air at the common temperature of the atmofphere contains 1550 degrees of heat, if a certain quantity of pure air, not in contact with any body that would immediately carry off the heat, fhould fuddenly be converted into fixed air and aqueous vapour, the heat contained in the former would raife the latter 1550 degrees multiplied by three, or 4650 degrees; and the temperature of red hot iron being 1050, it follows that the quantity of heat yielded by pure air, when converted into fixed air and aqueous vapour, is fuch (if it were not diffipated) as would raife the air and vapour fo changed to

more than four times the excefs of the heat of red-hot iron above the common temperature of the atmofphere. If, therefore, the abfolute heat which is difengaged from the air in refpiration were not abforbed by the blood, a very great degree of fenfible heat would be produced in the lungs.

Again, having proved that the fame heat which raifes venous blood 115 degrees will raife arterial only 100 degrees; the fame heat which raifes venous blood any given number of degrees will raife arterial a lefs number, in the proportion of 100 to 115, or of 20 to 23. But venous blood contains at leaft 1580 degrees of heat: hence, if a certain quantity of venous blood, not in contact with any body that would immediately fupply it with heat, fhould fuddenly be converted into arterial, the heat contained in the former would raife the latter only $\frac{20}{23}$ of 1580 degrees, or 1373 degrees; and confequently the fenfible heat would fuffer a diminution equal to the difference between 1580 and 1373, or nearly 200 degrees. But the common temperature of the blood is 96: when therefore venous blood is converted into arterial in the lungs, if it were not fupplied by the air with a quantity of heat proportionable to the change it undergoes, it's fenfible heat would be diminifhed 200 degrees, or it would fall from 96 to 104 below the zero of Fahrenheit.

That animal heat depends upon the feparation of elementary fire from the air in the lungs is likewife, according to Dr. Crawford, fupported by experiments made in fupport of the third and fourth propofitions. For from thofe of the third it appears, that when bodies are united with the inflammable principle they part with a portion of their elementary fire; and when this is again difengaged, they reabforb an equal portion of this fire from the furrounding bodies. It alfo appears, from thofe of the fourth propofition compared with the difcoveries of

Prieftley and Cavendifh, that when pure air is combined with the inflammable principle, in the ftate of light inflammable air, it is changed into aqueous vapour; but in the ftate of heavy inflammable air it is converted into fixed air; that wax, oil, and tallow confift chiefly of heavy and light inflammable air in a folid ftate; that, when pure air is altered by the combuftion of thefe fubftances, fixed air and aqueous vapour are produced, and the fame products are obtained when that fluid is altered by the refpiration of an animal. Hence it follows, that in refpiration and combuftion the pure air is altered in it's properties by combining with the inflammable principle: and fince we know that the union of thefe elements is univerfally accompanied with the extrication of heat, and a large quantity of elementary fire is difengaged from the air in the combuftion of oleaginous fubftances in particular, it may be concluded, that in the procefs of refpiration a fimilar extrication of fire takes place; and this is confirmed by fome experiments, the refults of which are, that when equal quantities of air are changed by the refpiration of an animal, and by the combuftion of a wax taper, the quantities of fenfible heat produced are nearly the fame.

It has alfo been proved, that the change the blood undergoes during it's circulation in the lungs is fimilar to that which folid bodies undergo when melted; *i. e.* their capacities are increafed: and fince when folid bodies are melted a quantity of heat is abforbed, it may be concluded, that when venous is changed into arterial blood a fimilar abforption takes place.

Laftly, experiments fhow, that when an animal is placed in a cold medium, the venous blood acquires a deeper hue, and a greater quantity of air is altered by refpiration in a given time than when it is in a warm medium. Now, Dr. Prieftley has proved that the livid colour of the venous blood depends upon it's union with

the inflammable principle: hence, the more the blood contains, the more it phlogifticates the air in the lungs in a given time, and a greater quantity of elementary fire is abforbed, in proportion as the animal is in a medium of a low temperature. Hence, the quantity of heat feparated from the air, and abforbed by the blood, is in all cafes proportioned to the neceffity: the elementary fire is therefore the true caufe of animal heat.

Source of animal heat, and the procefs of it's production.

Animal heat, therefore, depends upon a procefs refembling a chemical elective attraction. The pure air is received into the lungs containing a great quantity of elementary fire; the blood is returned from the extremities impregnated with the inflammable principle; the attraction of pure air to the latter principle is greater than that of the blood. This principle will therefore leave the blood to combine with the air: by this combination the air is obliged to depofit a part of it's elementary fire; and as the capacity of the blood is at the fame moment increafed, it will inftantly abforb that portion of fire detached from the air. The arterial blood, in it's paffage through the capillary veffels, is again impregnated with the inflammable principle; hence it's capacity for heat is diminifhed, as is fhown by experiments in proof of the fecond propofition. It will therefore, in the courfe of circulation, gradually give out the heat it received in the lungs, and diffufe it over the whole fyftem. Thus, in refpiration, the blood is continually difcharging the inflammable principle and abforbing heat, and in circulation continually imbibing this principle and emitting heat. But as heat is not proved to be a fubftance, Dr. Crawford does not mean to fay that elementary fire is capable of chemical combination; or to affirm that heat is difengaged from the air in refpiration by means of a double elective attraction: he only gives conclufions deduced from facts and experimental teftimony; and if it be ad-

mitted as a certain truth, that a *diminution* is produced in the quantity of heat contained in the air, and an *increaſe* in it contained in the blood, by reſpiration, it will not be denied that, in this proceſs, heat is continually paſſing from the air to the blood.

To this may be added, that as the blood by it's impregnation with the inflammable principle has it's capacity for heat diminiſhed, ſo, on the contrary, thoſe parts of the ſyſtem from which it receives this principle will have their capacity for heat increaſed, and will conſequently abſorb heat.

The capacities of thoſe parts which give out the inflammable principle are not however ſo changed as to abſorb all the elementary fire during circulation; for then it would be neceſſary to have recourſe to ſome other cauſe to account for the ſenſible heat produced in the circulation: hence, a part of the fire ſeparated becomes redundant. This is likewiſe ſupported by an extenſive analogy; for the proceſs by which the arterial blood is phlogiſticated during it's paſſage through the minute veſſels is ſimilar to that by which pure air is phlogiſticated in the combuſtion of oleaginous ſubſtances. In the latter proceſs, the inflammable principle is ſeparated from an earthy baſis, and combined with the air; in the former, it is ſeparated from the putreſcent parts of the ſyſtem, and combined with the blood. In both caſes, the capacity of the body which parts with it is increaſed, and that of the body which receives it, diminiſhed; and ſince in combuſtion a quantity of heat becomes redundant, the concluſion is, that the ſame happens in circulation. It muſt, however, be granted, that thoſe parts of the ſyſtem which communicate the inflammable principle to the blood have their capacity increaſed, and therefore a part of the fire ſeparated from the blood will be abſorbed; and to this cauſe is perhaps owing, that leſs heat is produced by an animal than by the burning of a wax taper, the quantities of air

Arterial blood phlogiſticated in the ſame way as pure air in combuſtion.

consumed being equal; for, probably, the putrescent juices as soon as they have given the inflammable principle to the blood fly off in the form of insensible perspiration, carrying a part of the fire detached in circulation: the portion of fire thus absorbed, however, is not very considerable, as appears from the quantity of heat which becomes sensible in the animal body. It therefore appears, that the blood in it's progress through the system gives out the elementary fire it had received in the lungs from the air, a small portion of which fire is absorbed by those particles which impart the principle to the blood, and the rest becomes redundant, or is converted into moving and sensible heat.

Part of the fire redundant.

Dr. Crawford then recites the principal facts relating to animal heat in the following manner:

Principal facts relating to animal heat.

1. He is of opinion, that the doctrine just stated explains the reason why breathing animals have a higher temperature than those which are not furnished with respiratory organs; for it has been proved, that the former are continually absorbing heat from the air; and it is probable, that to provide an apparatus for the absorption of heat, was the chief purpose of nature in giving to so great a part of the animal creation a pulmonary system, and a double circulation. The quantity of air changed by a man in a minute is found by experiment to be equal to that altered by a candle in the same space of time; and hence a man is continually deriving as much heat from the air as is produced by the burning of a candle. Naturalists have remarked, that the cold animals have also the power of keeping themselves at a temperature somewhat higher than the surrounding medium. It is probable that in these animals the aliment contains more absolute heat than the blood; for, as the blood during it's passage through the capillary vessels has it's capacity diminished, and hence is obliged to give out a part of it's

Animals with respiratory organs have a higher temperature than others which have not.

abſolute heat, the ſource from which it is again ſupplied, theſe animals having no lungs, and conſequently a want of reſpiration, is perhaps the aliment.

The production of cold in the animal body.

2. From the experiments of Dr. Fordyce made in heated rooms, it appears that the animal body has, in certain ſituations, the power of producing cold, or of keeping itſelf at a lower temperature than the ſurrounding medium. This could not ariſe ſolely from evaporation from the ſurface, as ſome have ſuppoſed, as the Doctor remained in moiſt air heated to 130 for 15 minutes, when the thermometer ſtood at 100 under his tongue, and ſtreams of moiſture ran from his whole body, from the condenſation of vapour, as appears from a ſimilar condenſation on the ſurface of a Florentine flaſk filled with water at 100. He found a dog could live without much inconvenience a conſiderable time in air at 260, the body of the animal being never raiſed more than two degrees above the natural ſtandard. That this generation of cold does not ariſe ſolely from evaporation, appears from ſome experiments made by Dr. Crawford upon living and dead frogs. A living and dead frog, equally moiſt and nearly of the ſame bulk, the former being at 67, the latter at 68, were laid upon flannel in air raiſed to 106. Two ſenſible thermometers were placed in contact with the ſkin under the axillæ, and the order of cooling was obſerved for 25 minutes.

Minutes.	Air.	Dead Frog.	Living Frog.
In 1	——	$70\frac{1}{2}$	$67\frac{1}{2}$
2	102	72	68
3	100	$72\frac{1}{2}$	$69\frac{1}{2}$
4	100	$72\frac{1}{2}$	$69\frac{1}{2}$
25	95	$81\frac{1}{4}$	$78\frac{1}{2}$

The thermometers being introduced into the ſtomach, the internal heat was found to be the ſame with that at the ſurface. Hence the living frog acquired heat more ſlowly than the dead one. A living and dead frog were

taken at 75, and immerſed in water at 93, the living frog being placed in ſuch a ſituation as not to interrupt reſpiration.

	Minute.	Dead Frog.	Living Frog.
In	1	85	81
	2	88½	85
	3	90½	87
	5	91½	89
	6	91½	89
	8	91½	89

Since therefore living frogs have the power of producing cold in warm water, as well as in warm air; and ſince the human body has the ſame power in a moiſt as well as in a dry air; we may conclude that this power does not ſolely depend upon evaporation. Dr. Crawford therefore explains it as follows:—It appears from experiment that the capacity of the blood for containing heat is ſo much increaſed in the lungs, that if it's temperature were not ſupported by the heat ſeparated from the air in reſpiration, or the parts adjacent, it would ſink 200 degrees. Hence, if evaporation from the lungs be ſo much increaſed as to carry off all the heat detached from the air, the arterial blood, when it returns by the pulmonary vein, will have it's ſenſible heat greatly diminiſhed, and will conſequently abſorb heat from the veſſels in contact with it and the neighbouring parts. The heat thus abſorbed in the greater veſſels will again be extricated in the capillaries, where the blood receives a freſh addition of the inflammable principle. If in this caſe the blood, during each revolution, were to be equally impregnated with it, the whole effect of the above proceſs would be to cool the ſyſtem at the centre, and convey the heat to that part of the body where it can be inſtantly carried off by evaporation. But it appears that, when an animal is placed in a heated medium, the blood is leſs impregnated; for the

venous blood in this cafe becomes gradually paler and paler, till it is nearly like arterial; and it is proved by Dr. Prieftley, that the livid colour depends upon combining with the inflammable principle in the minute veffels. Since, therefore, in a heated medium, it does not affume the fame livid hue, we may conclude it does not take in an equal quantity of the phlogiftic principle; and this conclufion is confirmed by experiments, which prove that the quantity of air an animal phlogifticates, in a given time, in a warm medium, is lefs than in a cold medium. It follows, from thefe facts, that the quantity of heat given by the blood in the capillaries will not equal what it had abforbed in the greater veffels, or pofitive cold will be produced. For example:—If the blood in paffing to the capillaries abforb from the greater veffels a quantity of heat as 200, and if, from not receiving a lefs impregnation of the phlogiftic principle than formerly, it give off at the extreme veffels a quantity of heat only as 150, a degree of refrigeration will be produced as 50; and this refrigerating caufe will continue to act while the colour of the venous is approaching the arterial, till it comes the neareft poffible; after which it will ceafe to operate. Thus, when animals are placed in a warm medium, the fame procefs which formerly fupplied them with heat becomes for a time the inftrument of producing cold, and probably preferves them from fuch rapid alterations of temperature as might prove fatal to life. Upon the whole, the increafed evaporation from the furface, and the diminution of that power by which the blood in it's natural ftate is impregnated with the phlogiftic principle, feem to be the great caufes on which the refrigeration depends. By the firft the animal is cooler at the furface, and by the fecond an accumulation of heat at the centre is obviated.

The power which animals poffefs of cooling themfelves at the centre, when placed in a medium above their natu-

ral heat, ſeems peculiarly neceſſary to preſerve life. For, as the heat received at the ſurface is ſpeedily, in ſuch caſes, carried towards the internal parts by the reflux of the heated fluids, if it were not abſorbed and rendered inſenſible by the change of the blood in the lungs, the central heat would probably ſoon be ſo increaſed as to deſtroy the vital principle.

3. The reaſon is now evident why animals preſerve an equal temperature during the great variations of the heat of the atmoſphere, ariſing from the changes of weather and difference of ſeaſon and climate. The equal tempera-tures of animals.

From experiments in proof of the fourth propoſition it appears, that in reſpiration the difference between the purity of the inhaled and expired air is increaſed by expoſing the animal to cold; and likewiſe the difference between the colour of the arterial and venous blood is augmented from the ſame cauſe. But the quantity of fire ſeparated from the air muſt be in proportion to theſe differences. For, as the extrication of heat from that element is produced by it's phlogiſtication, the more completely a given portion of air is phlogiſticated, the greater will be the quantity of heat detached from it. The ſame with reſpect to the phlogiſtication of the blood. It follows, as ſoon as by expoſure to cold an unuſual diſſipation of the vital heat is produced, the blood will begin to be more deeply phlogiſticated; hence will give more of it to the air, and in return get a greater portion of fire. In ſummer the reverſe will take place; the air will be leſs tainted by reſpiration, a ſmaller portion of the phlogiſtic principle will be attracted by the blood, and the quantity of fire abſorbed will be proportionably diminiſhed. Hence the heating and cooling powers in the animal body are ſo adjuſted to each other, as to produce an equal effect; and conſequently the law by which animals maintain an uniform temperature is ſimilar to that by which the temperatures of bodies

become fixed when they have arrived at the melting or freezing points. When freezing water, for example, is expofed to a cold atmofphere the quantity of elementary fire carried off by the furrounding air is precifely balanced by what is extricated from the water at the moment of congelation. In like manner, when an animal is expofed to a cold atmofphere, the quantity of heat carried off by the circumambient medium is balanced by what is detached from the blood in circulation. On the contrary, when ice is placed in a warm atmofphere, the whole of the heat it receives is rendered infenfible; and it has been fhown, that when an animal is placed in a warm medium, a fimilar extinction of the heat takes place.

Hence the power animals poffefs of generating heat is in all cafes proportioned to the demand. It is increafed by the winter colds, diminifhed by the fummer heats, and is totally fufpended, or converted into a contrary power, as the exigencies of the animal may require.

As the quantity of air an animal phlogifticates in a warm medium is not fo great as in a cold one, it follows, that in countries between the tropics the air will be lefs contaminated, ceteris paribus, by the refpiration of animals than in the temperate and frigid zones; and the difference is confiderable, if we recollect that the phlogiftication of a given quantity of air by an animal at the temperature of 50, was found to be twice as great as that produced by the fame animal in an equal time at 100. In thofe parts of the earth, therefore, in which the contamination of the air is increafed by the influence of heat upon *dead* animal fubftances, that element fuftains lefs injury from the refpiration of *living* animals.

An animal is hot in proportion to the air he breathes in a given time.

4. Among different animals, thofe are the hotteft which breathe the greateft quantity of air in proportion to their bulk; and in the fame animal the degree of heat is in fome meafure proportionable to the quantity of air inhaled

in a given time. Hence in exercife, by the action of the mufcles, the venous blood is returned from the extremities, in greater quantities than ufual, to the right auricle of the heart. By the action of the heart it is determined to the lungs. The refpiration is accelerated, the velocity of circulation increafed, and hence a proportionable increafe in the quantity of heat abforbed. The cold ftage of fevers is preceded by languor, and a diminution in the action of the heart and arteries. The refpiration is fmall, the quantity of blood which paffes through the lungs in a given time is diminifhed; and hence lefs phlogifton will be difcharged from the blood, and confequently lefs heat feparated from the air. In putrid fevers, as the folid and fluid parts of the fyftem are in a putrefcent ftate, and confequently retain the principle of inflammability with lefs force, a greater quantity of this principle will be difcharged from the lungs, the air will be more copioufly fupplied with it in the procefs of refpiration, and will, therefore, impart to the blood a greater proportion of it's abfolute heat. To thefe caufes it is probably owing, that the heat of the human body never rifes fo high as in putrid fevers.

5. Topical inflammation is accompanied with rednefs, tumour, and unufual heat. From the throbbing of the veffels, and from microfcopical obfervations, it appears that the velocity of the blood through the part inflamed is accelerated. Hence the blood is more copioufly fupplied with phlogifton, and a greater quantity of heat will therefore be extricated in a given time. This heat will ftimulate the veffels into more frequent and forcible contractions, by which the velocity of the blood, and the confequent extrication of heat, will be ftill further increafed. It is on this principle that, according to Dr. Crawford, we may perhaps account for the partial heats produced by topical inflammations, and for thofe in hectic and nervous

The increafe of heat in topical inflammation.

diseases. Heat in topical inflammations is accumulated by the increased velocity of the blood through the part inflamed, in the same manner as it is accumulated upon the fuel in combustion by directing a stream of fresh air into the fire.

Several conjectures that respiration and combustion arise from the same cause.

Mayow has already been considered as the first amongst the modern philosophers, who showed the cause of combustion and respiration to be the same. It however appears that several had preceded him, if not in experiment, at least in conjecture. Something was supposed to exist in the air, equally necessary to respiration and combustion, so early as the beginning of the seventeenth century. Pegelius, in a book entitled Thesaurus Rerum selectarum, magnarum, dignarum, utilium, suavium, pro Generis humani Salute oblatus, Auct. Magno Pegelio, 1604, says, "quod *aer respiratione attractus*, corpus totum subintret, et motum continue cum vita restituat et sustentet, et illud quod hinc continue exterius defluit et quod per os iterum ex interioribus seu ex toto egreditur, restituat et subimpleat; non secus quam *ignis ex aere attracto* et corpora excalefacta et ardentia penetrante subinde generatur et sic alitur." We are informed by Dr. Thornton that Hooke, in his Micrographia printed in Nov. 1664, had made some discoveries relative to the use of air in combustion and respiration, by which he preceded Mayow nearly four years; "the air being "a subject," says Hooke, "which (although all the "world has hitherto lived and breathed in, and been conversant about) has yet been so little explained, that a "diligent inquirer will be able to find but very little information from what has been (till of late) written upon "it: but being once well understood, it will, I doubt not, "enable a man to render an intelligible, nay, probable, "if not the true reason of all the *phenomena of fire*, "which, as it has been found by writers and philosophers

"of all ages, a matter of no ſmall difficulty, as may be "ſufficiently underſtood by their ſtrange hypotheſes and "unintelligible ſolutions of ſome few phenomena of it; "ſo will it prove a matter of no ſmall concern and uſe in "human affairs, when I come to ſhow the uſe of *air in* "*reſpiration*, and for the preſervation of the life; nay, "for the conſervation and reſtoration of the health and "natural conſtitution of mankind, as well as all other "aërial animals; as alſo the uſes of this principle or "property of the air in chymical, mechanical, and other "operations."

A third inſtance of the proceſs of reſpiration having been compared to combuſtion, is in the collection of Wedel, publiſhed at Jena in 1686; the title is, "G. W. Wedel Exercitat. Med. Phyſiol. &c. Jena, 1686," in which is a diſſertation, "Von der thieriſchen Wærme, Nutzen des Athemholers, &c.;" and finally, this reſemblance was obſerved by Dr. Black.

It appears, therefore, that the ſimilarity between combuſtion and reſpiration, or that the principle was the ſame that was conſumed in both, had already been noticed, although in a vague manner; but the properties and nature of this cauſe, which exiſts in the atmoſphere, had eſcaped their obſervation; and hence the moſt neceſſary part of the function of reſpiration was unknown; for, before any real light could be thrown upon this obſcure ſubject, ſeveral facts were neceſſary to be acknowledged.

1ſt. That caloric (matter of heat) is a conſtituent part of fluids, and that it is to this principle they owe their expanſibility, their elaſticity, and ſeveral other properties we know they poſſeſs.

2d. That the atmoſpheric air is compoſed of two aëriform fluids, *i. e.* of about one fourth part of vital air, and three fourths of azot gas.

3d. That the baſis of vital air, oxygen, is a principle

common to all acids, and that it is this which conſtitutes their acidity.

4th. That carbonic acid gas (fixed air) is the reſult of the combination of about 72 parts in weight of oxygen, and of 28 parts of carbon (pure charcoal).

5th. That leſs caloric enters into the compoſition of a given volume of carbonic acid gas, than of an equal volume of vital air; and that it is on this account that caloric is diſengaged during the combuſtion of carbon, *i. e.* during the converſion of vital air into carbonic acid gas by the addition of carbon.

6th. Laſtly, that water is not an element, nor a ſimple ſubſtance, as the ancients ſuppoſed, but that it is compoſed of 14.338 parts of oxygen, and of 85.668 parts of hydrogen.

Theſe facts being eſtabliſhed, a great deal was done in the explication of the production of animal heat.

From the ſuppoſition of the Stahlians, air was phlogiſticated by reſpiration as well as by combuſtion; but Lavoiſier announced in 1777, in a memoir read to the Academy, that reſpiration was a ſlow combuſtion of a portion of carbon which the blood contains, and that animal heat is cauſed by a portion of the caloric that is diſengaged at the moment of the converſion of the vital air of the atmoſphere into carbonic acid gas, as happens in the combuſtion of charcoal; but he offered it only as a very probable conjecture: whilſt Crawford, who had diſcovered the cauſe of it nearly at the ſame time as Lavoiſier, and in the ſame year, publiſhed his very intereſting work in 1779, in which he collected a number of experiments to realize this ſuſpicion. In 1788 a very enlarged edition of this work appeared, from which the account given of his doctrine is taken, and from which it ſeems that Dr. Crawford ably ſupports the phlogiſtic ſyſtem.

The experiments which Lavoiſier and de la Place

publifhed in 1780 confirm the opinion the firft chemift had conceived, and totally overturned the theory of phlogifton. To determine the effects of refpiration and combuftion upon air, thefe two chemifts introduced a guinea-pig under a glafs veffel containing 248.01 inches of pure air, and let it remain there an hour and a quarter. After having taken away this animal, by making it pafs through the mercury, and left the interior air to become of the temperature of the atmofphere, it was reduced to 240.25 inches. Having afterwards abforbed the fixed air by cauftic alkali, there remained 200.56 inches of air. In this experiment, therefore, there were 46.62 inches of pure air changed, and 37.96 inches of fixed air produced, making an allowance for the fmall quantity of fixed air contained in the pure air of the veffel. Now of the volume of pure air thus changed, 0.814 will be it's volume diminifhed by refpiration; whilft in the combuftion of charcoal the volume of air is diminifhed in the ratio of 1 to 0.74828. This difference may in fome degree arife from the difference of meafure, but perhaps more fo from letting a little of the exterior air penetrate into the veffel on introducing the animal.

Effects of refpiration and combuftion compared by Lavoifier and de la Place.

The weight of the fixed air produced in the above experiment is 26.572 grains; from which it follows, that in the fpace of ten hours the animal would have produced 212.576 grains of fixed air.

On determining the quantity of fixed air produced by a guinea-pig in common atmofpherical air, it was found to amount to 236.667 grains in ten hours; which differs about one ninth from the preceding experiment, arifing probably from the difference of fize in the two animals.

A third experiment, made upon a guinea-pig in dephlogifticated air, afforded 226 grains of fixed air in ten hours.

On taking the medium of thefe experiments, and fome

others made by thefe chemifts, both in dephlogifticated and atmofpherical airs, it appears that the quantity of fixed air generated by the refpiration of the guinea-pig in ten hours amounts to 224 grains. Since thefe experiments were made at a temperature of 14 or 15 degrees, thefe chemifts think it poffible that the quantity of fixed air may be fomewhat lefs than at a temperature of zero, which was that of the interior part of the veffels: hence, to be more exact, the products of fixed air ought to be determined at this laft temperature. Having proved, by experiment, that in the combuftion of charcoal the formation of one ounce of fixed air is able to melt 26.692 ounces of ice, it follows that the formation of 224 grains of fixed air ought to melt 10.38 ounces. Confequently this quantity of melted ice reprefents the heat produced by the refpiration of a guinea-pig during ten hours.

In the experiment on the animal heat of a guinea-pig, it was taken from under the glafs veffel nearly of the fame heat with which it was introduced; for it is well known that the interior heat of animals is always nearly the fame, but, without a continual renewal of this heat, what it poffeffed at firft would be entirely diffipated, like that of n inanimate body: this heat therefore which it communicates to the furrounding fubftances, and which in this experiment was communicated to fome ice placed under the veffel, of which it melted in ten hours thirteen ounces, is renewed by it's vital functions. This quantity of melted ice reprefents, therefore, nearly the heat renewed in that fpace of time by refpiration. Perhaps it may be neceffary to fubtract a couple of ounces or more, fince the extremities of the body of the animal became cooled in the veffel, although the interior of the body preferved nearly the fame temperature: befides, the humours evaporated by it's internal heat melted, on cooling, a fmall

quantity of ice, and united with the water which ran from the veffel.

On deducting, therefore, about two ounces and a half from this quantity of ice, the remainder will be the quantity melted by the refpiration of the animal; and if the errours which are inevitable in fuch experiments be confidered, perhaps a more perfect coincidence between thefe refults cannot be expected.

Hence, according to thefe chemifts, the heat difengaged during the converfion of pure into fixed air by refpiration may be confidered as the principal caufe of the prefervation of animal heat; and if other caufes concur in it's fupport, their effect is inconfiderable.

From thefe experiments thefe chemifts conclude that refpiration is a combuftion, which, although very flow, is perfectly fimilar to that of charcoal; that it takes place in the interior part of the lungs without difengaging any fenfible light, becaufe the matter of fire, become free, is immediately abforbed by the humidity of thefe organs; that the heat thus extricated in this combuftion is communicated to the blood which traverfes the lungs, and is from thence diftributed all over the fyftem. Hence the air we breathe ferves two purpofes equally neceffary to our prefervation—it takes from the blood the bafis of the fixed air, the fuperabundance of which would be hurtful; and the heat depofited in the lungs by this combination repairs the continual lofs of heat brought about by the atmofphere and furrounding bodies.

Refpiration is a perfect combuftion.

Animal heat is nearly the fame in all parts of the body; which effect appears to depend on the three following caufes:

Caufes of the equality of animal heat.

1ft. The rapidity of the circulation of the blood, which tranfmits immediately, even to the extremities of the body, the heat it receives in the lungs.

2d. The evaporation produced by the heat in thefe organs, and which diminifhes the degree of their temperature.

3d. The augmentation obferved in the fpecific heat of the blood, when it is deprived of the bafis of fixed air it contains by the contact of the pure air: hence, a part of the fpecific heat developed in the formation of the fixed air is abforbed by the blood, it's temperature remaining always the fame; but when in the circulation the blood comes to receive again this bafis of fixed air, it's fpecific heat diminifhes, and fome heat is extricated; and as this combination is made in all parts of the body, the heat it produces contributes to fupport the temperature of the parts diftant from the lungs nearly at the fame degree as that of thefe organs. From this way of reafoning the chemifts eftablifh the following propofitions:

When an animal is in a permanent and tranquil ftate, when it is able to live a confiderable time without fuffering in the medium that furrounds it: in general, when the circumftances in which it is do not fenfibly change it's blood and humours, fo that the animal fyftem after feveral hours undergoes no fenfible variation, the prefervation of the animal heat is owing, at leaft in great part, to the heat produced by the combination of the pure air refpired by animals with the bafis of the fixed air furnifhed by the blood.

Hence, on comparing the heat difengaged by the combuftion of charcoal with the quantity of fixed air formed during this combuftion, the heat developed in the formation of a given quantity of fixed air is obtained: if, then, the quantity of fixed air produced by an animal in a given time be determined, the refult will be the heat arifing from the action of it's refpiration on the air; and it only remains to compare this heat with that which fupports it's animal heat, and to meafure the quantity of ice it

melts in the interior of the veffel: and if, as has been found by the preceding experiments, thefe two quantities of heat are nearly the fame, it may be concluded that it is to the change of pure into fixed air by refpiration that the prefervation of animal heat is owing, at leaft for the moft part.

In refpiration, as in combuftion, it is the air of the atmofphere that furnifhes the oxygen and the caloric; but as in refpiration it is the fubftance even of the animal, the blood, which furnifhes the combuftible part, if animals did not habitually repair by nourifhment what they lofe by refpiration, the oil would foon be wanting to the lamp, and the animal would perifh like an extinguifhed candle. There are even inftances cited by authors of this combuftion being fo rapid as to confume the greater part of the body. Thus a female defcribed by Wilmer, or the inflammable woman of Coventry; the countefs Cornelia Bandi, near Cefena, in Romagna; another woman at Chrift-church, in Hampfhire; and Grace Pots, at Ipfwich; were confumed by an internal fire, fo eager were the principles of which they were compofed to combine, as Dr. Beddoes fays, with oxygen. Thefe remarkable inftances, however, of quick combuftion carried on in the body are very rare.

Extraordiry cafes of rapid animal combuftion.

The proofs therefore of this identity of effects between refpiration and combuftion are taken immediately from experience. Indeed, the air that has been refpired no longer contains, at it's departure from the lungs, the fame quantity of oxygen; it contains not only carbonic acid gas, but likewife much more water than it did before infpiration. Now, fince vital air cannot be converted into carbonic acid gas without the addition of carbon, or into water without hydrogen; and fince this double combination cannot take place without the vital air lofing a part of it's fpecific heat, the confequence is, that the effect of

refpiration is to extract a portion of hydrogen and carbon from the blood, and to depofit in their place a portion of it's fpecific caloric, which during circulation is diftributed with the blood into all parts of the animal œconomy, and fuftains that temperature obferved in all refpiring animals, and which, if nothing extraordinary happen, is nearly conftant. It may therefore be faid with the ancient poets, that the torch of life is lighted the moment the infant breathes; a gentle combuftion, productive of the vital flame, which is only extinguifhed by death. Since, during refpiration, a great quantity of carbon and hydrogen from the blood is converted by uniting with the oxygen of the air into carbonic acid gas and water, and confequently a great deal of caloric let loofe; Lavoifier and Seguin have made fome experiments to endeavour to find the quantity of carbonic acid gas and water which is formed; and as there is an aqueous emanation not only from the lungs, but alfo from the furface of the body, which is called *perfpiration*, they were likewife defirous of knowing the quantity extricated from fo large a furface, and of comparing, as near as circumftances would permit, the connexion arifing between refpiration, perfpiration, and digeftion. The invifible vapour or emanation that takes place from the furface of the body they have called *cutaneous perfpiration*; and that which is extricated from the lungs at each expiration, *pulmonary perfpiration.*

Experiments of Seguin and Lavoifier to determine the quantity of carbonic acid gas and water formed during refpiration, &c.

Sanctorius was the firft who undertook to make experiments on the cutaneous perfpiration: for this purpofe he placed himfelf in a chair adapted to a pair of fcales, and he determined the quantity of perfpiration by the lofs of weight he experienced.

Before his time, nothing but conjecture determined the effects of this cutaneous function; and although this philofopher was the firft experimental inquirer on the fubject, many things were wanting to make him fuccefsful.

3

The phenomena of refpiration, and the formation of water and carbonic acid which accompanies it—the two fpecies of evaporation, one of which is effected by folution in the air, and the other by the fimple combination of caloric with the evaporated liquor, were unknown. It was not even fufpected that the principal caufes which influence refpiration are the greater or lefs denfity of the air, it's temperature, and it's degree of drynefs or humidity. Sanctorius, deprived of thefe preliminary facts, confounded all the effects which arofe from his experiments.

In order to feparate the cutaneous perfpiration, thefe two chemifts made ufe of a garment of filk, coated with elaftic gum, fo as to prevent the air and humidity from penetrating. When this was put on, it was tied at the top of the head by a ftrong ligature, whilft a tube was adapted to the mouth, fo as not to let any air efcape, to breathe through: hence, whatever was refpired paffed externally, and whatever perfpired, internally.

By being weighed on entering this apparatus, and after having departed from it, the difference gave the lofs of weight owing to the united effects of refpiration and perfpiration; and by being weighed a few inftants after having entered and before departing from it, the lofs of weight owing only to the effects of refpiration was obtained.

The greateft difficulty which the chemift had to contend with was the feparation of the products of refpiration, of pulmonary and of cutaneous perfpiration; for it is neceffary to know, that there continually oozes into the lungs an humour feparated from the blood, which filters through the membranes of the lungs, and which is compofed principally of hydrogen and of carbon.

It is this humour which, being greatly divided at the moment it comes from the fmall extremities of the exhaling veffels of the lungs, is in part confumed by decompofing

the vital air with which it was in contact, and forms during this combuſtion water and carbonic acid gas. It is not aſtoniſhing that this combuſtion ſhould exiſt in the lungs, when it is ſeen that dung, the nature of which approaches much to that of blood, burns at the ordinary temperature of the atmoſphere, *i. e.* at 8° or 10°.

The carbonic acid gas therefore, formed during reſpiration, being in a fluid ſtate, it is eaſily conceived how it is evacuated by the action of the lungs at the moment of expiration; but the caſe is not ſo with the water formed at the ſame time. It would ſoon accumulate in the bronchia, if nature had not the means of evacuating it, one of which is this. The air enters cool into the lungs; it departs from it with a heat nearly equal to that of the blood: now the hot air diſſolves more water than cold air, and it is from this increaſe of caloric that it carries away with it the water exiſting in the lungs.

This water is of two ſorts; 1. that which oozes with the carbonated hydrogen, or the water of pulmonary perſpiration, properly called. 2. That which is formed by the combination of the oxygen of the air with the hydrogen of the blood, or the water of reſpiration.

Theſe chemiſts were able to obtain the reſpective quantities of theſe two portions of water.

The apparatus they made uſe of was ſo diſpoſed as to be able to meaſure, with great exactitude, the quantity of water and of carbonic acid exhaled, as well as the quantity of air before and after the experiment; for it is eaſily conceived, that being acquainted on the one ſide with the total ſum of the water come from the lungs, and on the other, the quantity of carbonic acid gas formed, it would be eaſy to determine, by a very ſimple calculation, the quantity of water formed, and the quantity of water owing to the pulmonary perſpiration. But in the ſolu-

tion of this problem, it is taken for granted, that all the carbonic acid gas disengaged at each expiration is formed in the lungs, and during circulation.

If the carbonic acid gas disengaged during expiration was in part the product of digestion, the consumption of vital air in the act of respiration must be attributed to another cause. The supposition must be, that more water is formed, either in the lungs or during circulation; and then the pulmonary perspiration would be found to be diminished by all the quantity of water which must be attributed to this formation; or it must be granted, that a part of the vital air, being absorbed in the lungs, unites during circulation with some part of our system.

The increase of menstrual power, which the air acquires by being heated in the lungs, is in general sufficient to evacuate, by way of solution, the two portions of water just mentioned; viz. that arising from the pulmonary perspiration, and that formed by the combination of oxygen and hydrogen. In this respect, nature appears to make use of some very curious means of compensation. If the quantity of water which oozes through the bronchial membranes be too abundant; if the air of respiration, already loaded with water that is formed, is not in a state to dissolve it in spite of the efforts of a more accelerated respiration, and in spite of the increase of caloric proceeding from it, which increases the menstrual power of the air; the excess is carried back again into the circulation by the absorbent vessels of the lungs, or expectorated under another form.

It is easy to conceive how all these causes must influence the phenomena of perspiration; that it is accelerated or retarded according to the necessity of the machine—that it ought sometimes to form more water, sometimes more carbonic acid gas—that, in short, the pulmonary perspiration can be augmented or diminished by an infinity of circumstances.

Theſe chemiſts found, that the loſs of weight of a perſon in an ordinary ſtate varies from 11 grs. a minute to 32; *i. e.* in 24 hours from 1 lb. 11 oz. 4 drs. to 5lbs. comprehending the effects of cutaneous and pulmonary perſpiration, and of reſpiration. Taking the medium, the loſs of weight is 18 grs. per minute; and ſuppoſing it to continue uniformly, it will be 1 oz. 7 drs. an hour, and 2 lbs. 13 oz. in 24 hours.

	lb.	*oz.*	*drs.*
Of theſe 2 lbs. 13 oz. there belong to cutaneous perſpiration - - - -	1	14	0
And to the effects of reſpiration - -	0	15	0
Total - -	2	13	0

On decompoſing the effects of reſpiration, it will be found, on a medium,

1. That an individual conſumes 38413 cubic inches of vital air in 24 hours, *i. e.* a little more than 22 cubic feet, or 33 oz. 1 dr. 10 grs.

2. That of this quantity there is employed to form water a little more than - - -	13 cubic feet,
And to form carbonic acid a little leſs than - - -	9
	22

	lb.	*oz.*	*drs.*	*grs.*
3. That the volume of carbonic acid gas, diſengaged from the lungs in 24 hours, is 14930 cubic inches, *i. e.* about 8 feet 6 cubic inches, which are compoſed of carbon -	0	5	7	[illegible]
oxygen -	0	12	0	4
Total - -	1	1	7	4

4. That the weight of the water, formed in the lungs in 24 hours, amounts to 1 lb. 7 oz. 5 drs. 20 grs., which are compofed of

	lb.	oz.	drs.	grs.
Hydrogen	0	3	3	10
Oxygen	1	4	2	10
Total	1	7	5	20

5. That the quantity of water difengaged ready formed by pulmonary perfpiration, is 5 oz. 5 drs. 62 grs. in 24 hours.

	lb.	oz.	drs.	grs.
Laftly, That uniting together the water difengaged in 24 hours, by cutaneous perfpiration, which amounts to	1	14	0	0
That difengaged by pulmonary perfpiration	0	5	5	62
The quantity of carbon confumed in the fame time	0	5	7	0
And the quantity of hydrogen	0	3	3	10
The total lofs of weight of a perfon in 24 hours is	2	13	0	0

Thefe refults are only to be eftimated as probable. Seguin and Lavoifier have likewife obferved, that without being very particular in taking daily the fame quantity of nourifhment; without reftraining themfelves to live by rule, provided excefs and irregular hours of repaft are avoided; the fame individual, after having been increafed in weight by all the aliments, returns every day, after the revolution of about 24 hours, to the fame weight he had the evening before. If this effect does not take place, it is the confequence of difeafe.

It is by experience only that man can become ac-

quainted with nature; and the more he interrogates her, the more will he be delighted with her wisdom. "Our "admiration," says the chemist, "cannot be fatigued "with viewing the system of general liberty which na-"ture appears to have been desirous to establish in every "thing relative to the animal machine. In giving it life "and spontaneous motion, an active energy, necessities "and passions, she has not interdicted the use of them. "She was even desirous that he should be free in their "abuse, but prudent and wise; she has every where sur-"rounded him with regulators; and she has added sa-"tiety to the superabundance of enjoyment."

Animal machine governed by three principal regulators.

The animal machine is therefore governed by three principal regulators: *respiration*, which by operating in the lungs, and perhaps likewise in other parts of the system, a slow combustion of the hydrogen and carbon contained in the blood, produces a disengagement of caloric absolutely necessary to the support and existence of animal heat: *perspiration*, which, by occasioning a loss of the perspirable humour, facilitates the disengagement of a certain quantity of caloric necessary to the solution of this humour in the surrounding air; and consequently prevents, by the continual coldness this disengagement produces, the individual from receiving a degree of heat or temperature superior to what is fixed by nature: and *digestion*, which, furnishing the blood with water, hydrogen, and carbon, restores habitually to the animal machine what it loses by perspiration and respiration, and afterwards rejects externally substances that are hurtful or superfluous to it.

If the causes which affect man are various, his resources are equally multiplied: his temperament is either adapted for motion or repose, for abstinence or excess of nourishment. Similar circumstances permit him to pass from an active to a tranquil life, according to his neces-

fities or his will. If he be in a ftate of inaction and repofe, the circulation is flow as well as the refpiration, he confumes lefs air, exhales lefs carbon and hydrogen from the lungs, and confequently has lefs need of nourifhment. If he be obliged to work hard, the refpiration is accelerated; he confumes more air, lofes more hydrogen and carbon, and confequently has need of oftener repairing what is loft, by a greater quantity of nutrition. In running, dancing, and in all violent exercifes, whatever acceleration the refpiration and circulation undergo, or whatever increafe there is in the confumption of air, of hydrogen and carbon, the equilibrium of the animal œconomy is not difturbed, whilft the aliments more or lefs digefted, always more or lefs in referve in the inteftinal canal, fupply their lofs; but if the expenfe made by the lungs be greater than the receipt made by nutrition, the blood is deprived by degrees of it's hydrogen and carbon, and difeafe fucceeds. In this cafe the animal is advifed of the danger by laffitude, lofs of vigour, and he finds the neceffity of reeftablifhing the equilibrium by nourifhment and repofe. The contrary takes place, for want of motion and exercife or the ufe of certain aliments, or any imperfection or vice in the organs of nutrition or refpiration. In thefe cafes, the digeftion introducing into the blood more matter than the refpiration can confume, an excefs of carbon or of hydrogen takes place in the mafs of blood, or perhaps both at the fame time. Nature then ftrives againft this alteration in the humours; and if fhe cannot recover the equilibrium by a more frequent refpiration, difeafe is the confequence.

"Whilft," fay thefe two chemifts, "we only con-
" fidered the confumption of air in refpiration, the lot
" of the rich and the poor was the fame, for the air be-
" longs to all, and cofts nothing: the labourer even,
" from his greater energy, enjoys more completely this

"gift of nature: but fince experience has proved re-"fpiration to be a real combuftion, that confumes at "each inftant a portion of our fubftance, that this con-"fumption is the greater in proportion as the circulation "and refpiration are accelerated, that it increafes accord-"ing to the more laborious and active life of the indi-"vidual—a multitude of moral reflexions arife of them-"felves from fuch effects. By what fatality happens it "that the poor man, who lives by the fweat of his brow, "and is obliged to expend the force which nature allots "him, confumes more than his idle neighbour, whilft "this laft has lefs need of repairing?"—"Why," exclaim thefe humane chemifts, "by a fhocking con-"traft, does the rich man enjoy an abundance which is "not phyfically neceffary for him, and which would "feem to be deftined for the daily labourer? Let us "not however calumniate Nature, and accufe her of "faults that undoubtedly belong to human inftitutions, "and which are perhaps not to be feparated from them. "Let us be content to blefs philofophy and humanity, "which unite to procure us fuperior enjoyment and "happinefs, and add to thofe of the indigent."

This refult of forces continually varying and continually poifing each other, which are obferved at each moment in the animal œconomy, is truly to be admired. Man, in this refpect, has been more favoured by nature than any other animals; he lives equally in all temperatures and in all climates: if he finds himfelf in a cold climate, the contact of the air with the lungs, from it's greater denfity, becomes more confiderable; more air is decompofed, more caloric difengaged, which repairs the lofs caufed by the external cold; whilft the perfpiration diminifhes, evaporation becomes lefs, and confequently the cold.

If he paffes into a hot climate, the contrary effect takes

place. The air being lefs denfe, it's contact with the blood is lefs confiderable; lefs air is decompofed, lefs caloric is difengaged, a more abundant perfpiration is eftablifhed, a greater quantity of heat taken away; and it is in this manner that an almoft uniform degree of heat is obferved in animals that breathe, which is about 32° of Reaumur.

Whilft the variation of the effects does not pafs over the limits affigned by nature, whilft the means of compenfation fhe employs are fufficient, the animal is in a ftate of health. But if the refpiration takes more or lefs hydrogen and carbon by the lungs, than digeftion can fupply; if the perfpiration and frigidity it occafions in concert with the exterior air do not take away all the caloric arifing from the decompofition of the vital air in the lungs, or in any other part of the fyftem; if, in fhort, throughout, the receipt is not equal to the expenfe, the animal machine is foon difturbed, and the blood changes it's quality, either from excefs or want of hydrogen and of carbon, or both at the fame time.

Thefe two philofophers therefore, Crawford and Lavoifier, agree in looking upon the pure air as the principal fource of the heat extricated in combuftion and refpiration: but there appears to be an effential difference in their opinions, which confifts in this, that Lavoifier thinks, that the heat, difengaged during thefe two proceffes, is combined with the pure air; and that this fluid owes it's aëriform ftate to the expanfive force of this combined heat: inftead of which, according to Crawford, the matter of heat is in a free ftate in the pure air; and it is only difengaged, from the pure air lofing a great part of it's fpecific heat on combination. Crawford fupports this affertion by experiments, by which he finds the fpecific heat of pure air to be 87 times greater than that of common water. Difference between Lavoifier and Crawford.

Girtanner. Girtanner differs in opinion from Lavoifier and Crawford: he believes, that during refpiration one part of the oxygen of the vital air combines with the venous blood, the deep colour of which it changes to a vermilion; that a fecond portion of the oxygen unites to the carbon contained in the carbonated hydrogenous gas, which exhales from the venous blood, and forms carbonic acid gas; that a third portion of the oxygen unites to the carbon of the mucus which the lungs contain in large quantity, and which is continually decompofing. This part likewife forms carbonic acid gas. A fourth part of the oxygen combines with the hydrogen gas of the blood to form water, which exhales during refpiration. The caloric which the decompofed vital air contained *remains in part united* to the oxygen and to the blood: hence the quantity of fpecific heat of the arterial blood, which is greater than that of the venous; another part of the caloric enters into the combination of the carbonic acid gas; and, laftly, a third part produces the neceffary temperature for the formation of water, by the combination of hydrogen and oxygen gafes: confequently the *effects* of refpiration fhould be,—

1. The venous blood lofes the carbonated hydrogenous gas it contains, and abforbs oxygen gas, which gives it a vermilion colour, fuch as it gives to metallic oxyds, to the nitrous acid, and to feveral other fubftances with which it is combined.

2. The capacity of the blood is augmented, becaufe oxygen increafes the capacity of all fubftances with which it unites.

3. The oxygen gas of the atmofphere is in part abforbed by the venous blood, partly changed into carbonic acid gas, by the carbon of the blood and that of the mucus of the lungs, and partly into water by the hydrogen gas of the blood, and the great quantity of caloric become free.

The *products* of refpiration fhould be,

1. A fluid animal oxyd; 2. carbonic acid gas; 3 water; 4. a fmall quantity of caloric become free.

Hence it follows, that refpiration is a procefs exactly analogous to combuftion and the oxydation of metals; during circulation the blood lofes it's oxygen, and becomes loaded with carbonated hydrogenous gas, by means of a double affinity; during the diftribution of oxygen through the fyftem, the caloric united to this oxygen becomes free, and produces animal heat; and the greater capacity of arterial blood for caloric is only owing to the oxygen to which it is united in the lungs.

Another opinion refpecting the procefs of refpiration is that of de la Grange. Confidering that, if all the heat diftributed through the animal fyftem arofe in the lungs, their temperature would be fo very great as to caufe fear left it fhould conftantly deftroy them; and that, if the temperature of the lungs is fo extraordinarily different from that of the other parts, it muft have been long ago obferved; he thinks he can conclude with great probability, that all the heat of the animal œconomy is feparated not only in the lungs, but in all parts wherever the blood circulates. For this purpofe, he therefore fuppofes, that the blood on paffing through the lungs diffolves the oxygen of the infpired air; that this diffolved oxygen is conveyed by the blood into the arteries, and thence into the veins; and that during circulation the oxgen quits by degrees it's ftate of folution to combine partially with the carbon and hydrogen of the blood, and form the water and carbonic acid which is extricated from it as foon as the venous blood goes from the heart in order to enter the lungs; and from this manner of explanation this chemift thinks that the fmall difference may be eafily accounted for which is found between the temperature of the lungs and that of the other De la Grange.

internal animal parts, and how the caloric may arrive at the extreme parts the moſt diſtant from the lungs.

Haſſenfratz. The opinion of Haſſenfratz reſembles the laſt: he thinks that caloric is not only diſengaged in the lungs, but during the circulation by the union of the hydrogen and carbon of the blood with the oxygen which is intermixed with it; and as caloric is extricated during this union, and this caloric ſupports the animal heat; and as this union takes place for the moſt part during the circulation of the blood as it paſſes from the lungs into the arteries, and thence by the veins into the lungs, it follows, that the greateſt part of the caloric is ſeparated during this circuit. This chemiſt explains the experiment of Dr. Crawford, or gives the cauſe why the arterial blood acquires a greater ſpecific heat than the venous; and this he ſays may be done two ways:—1. As all oxydated ſubſtances have a greater proportionable heat than ſimple ſubſtances, and as the arterial blood with reſpect to the venous may be looked upon as oxydated, the firſt muſt have a proportionably greater heat than the laſt. 2. As the oxygen in the arterial blood ſtill contains almoſt all it's caloric, and this is afterwards extricated in circulation by the union of the oxygen with the hydrogen and carbon of the blood—the venous, in which this combination is made, contains no more caloric, it having been diſengaged and diſperſed to warm all the parts through which the blood has paſſed: hence the venous blood ought to have comparatively leſs heat than the arterial. Hence the lungs are not the ſtove of animal heat, but the caloric in order to ſupport it is extricated during circulation.

Gren. According to Gren, the oxygen gas does not give up it's baſis to the arterial blood: he aſſerts, that all the water we expire is of new formation, and not ſeparated from the blood; that conſequently oxygen is only ab-

forbed for the formation of water and of carbonic acid, and that there remains none of it to combine with the blood: further, that the change of the venous into the arterial blood in the lungs does not depend upon the abforption of oxygen, but on the feparation of the carbon and hydrogen; and that the arterial and not the venous blood is a ftimulus to the heart.

Another theory on this fubject is given by de la Metherie. This chemift does not believe the conclufions drawn by Lavoifier and Seguin, having found that, De la Metherie.

1. In an ordinary infpiration, no more than from four to fix inches of air enter the lungs.

2. He admits three caufes of animal heat.

a. Caloric, which is difengaged from the pure air that undergoes a combination in the lungs.

b. Mufcular motion; for in fleep the animal heat is lefs than when awake; and in local inflammation, the heat of the part is confiderably raifed.

c. Finally, the fermentation of animal fubftances in the ftomach and inteftines, during which fermentation caloric is difengaged; for animal matter during this procefs is known to be heated even to the point of inflammation.

3. Refpiration likewife ferves as a conductor of the electric fluid; for, from the experiments of Read, the air of an apartment in which a perfon has breathed for a few hours is always electrified negatively, whilft before it was in a pofitive ftate of electricity.

The laft theory on refpiration is that of Davy. This ingenious philofopher having from experiment laid it down as a fact that the caloric of the fyftem of Lavoifier is not the matter of heat, or an imaginary fluid, as has been fuppofed; but that it may be defined a peculiar motion, or probably a vibration of the corpufcles of bodies tending to feparate them; and hence may with Davy.

propriety be called *repulſive motion*; and having ſubſtituted for oxygen gas the term phos-oxygen (from φως light, οξυς acid, and γεννητωρ generator), to expreſs a chemical combination of the ſimple ſubſtance light with the ſimple ſubſtance oxygen; having proved that the oxygen gas of the French nomenclators, which they have ſuppoſed to be oxygen combined with caloric, is a ſubſtance compounded of light and oxygen; and having explained the theory of combuſtion; he firſt offers ſome objections againſt the theory of reſpiration of the caloriſts.

1ſt. Againſt it's being ſuppoſed that one portion of the oxygen combines with the iron in the blood, giving the vermilion colour to the arterial blood, he aſſerts that iron never decompoſes phos-oxygen at ſo low a temperature as 98°, the greateſt heat of the lungs; and phos-oxygen is never decompoſed by iron, without rapid combuſtion, flame, and great heat.

2d. Oxygen gas is never decompoſed by carbon at ſo low a temperature as 98°, and is never decompoſed without combuſtion, &c.

3d. There is never a decompoſition of phos-oxygen by hydrogen at ſo low a temperature; and it is well known that this proceſs does not take place without flame: hence the theory is falſe. On the contrary, Davy undertakes to prove from experiments,

1ſt. That phos-oxygen (light and oxygen) is not decompoſed in the lungs;

2d. That phos-oxygen combines with the venous blood in the lungs;

3d. That carbonic acid and water are both liberated from the lungs during this proceſs, either by the increaſe of temperature, or from the ſuperior affinity of phos-oxygen for the venous blood.

First experiment. A phial containing twelve cubic inches and a half was filled with very pure phos-oxygen. The medial vein of a

healthy man was opened, and the ftream of blood directed into the phial. The mouth of the phial was immediately brought into contact with the arm, fo as entirely to exclude all external air.' The room was then darkened. As the blood flowed into it, it changed from a dark red to a bright vermilion colour. When the phial was half full, it was clofed, and plunged in mercury heated to 90°. Having remained half an hour, the blood was found coagulated, and a bright vermilion colour: fome drops of water were formed on the fides of the phial. When the cork was drawn, about two cubic inches of mercury rufhed into the phial; from which he concluded an abforption of gas had taken place. The remaining gas was three cubic inches and one tenth of phos-oxygen, with nine tenths of a cubic inch of carbonic acid.

During the experiment no light was liberated: hence Davy fuppofes there was no decompofition of phos-oxygen. And as a confiderable diminution of phos-oxygen took place, and the blood acquired new properties, he concludes that phos-oxygen is capable of combination with the venous blood. To prove this by analyfis as well as fynthefis, he made the following experiment:

A twelve-cubic-inch phial, with a pneumatic apparatus affixed to it, was filled with arterial blood from the carotid artery of a calf. The phial was placed in a fand bath of the temperature of 96°, and the heat gradually and flowly raifed. In about ten minutes the temperature of the bath was 108°, and the blood began to coagulate. At this moment fome globules of gas were perceived paffing through the tube. Gas continued to pafs, in very fmall quantities, for about half an hour; when the temperature of the fand was about 200°. The blood was coagulated, and almoft black. About one cubic inch and eight tenths of gas were collected in the mercurial apparatus: of this one cubic inch and one tenth were carbonic acid, and the

Second experiment.

remaining feven tenths phos-oxygen. Great caution is neceffary in this experiment; for, if the temperature is not gradually and flowly increafed, the liberated gafes are carbonic acid and hydrogen.

From the above experiment it is evident that the arterial blood contains phos-oxygen; and it was before proved by fynthefis that it is capable of combining with it directly: hence he concludes that phos-oxygen combines with the venous blood of the fyftem in the pulmonary veffels.

As no light was liberated in the firft experiment, it is evident there cannot be even a partial decompofition of phos-oxygen in refpiration; and confequently, the carbonic acid and aqueous gas liberated cannot arife from the decompofition of phos-oxygen by the carbon and hydrogen of the venous blood—they muft therefore be liberated from the venous blood. To prove this more clearly, the following experiment was made:

Third experiment.

A fmall fheep's bladder was filled with blood from the medial vein of a healthy woman. This blood never came into contact with any air during the experiment. The bladder was inferted in a veffel of water heated to 112°, and the gafeous products received by a pneumatic apparatus. They were carbonic acid and aqueous gas.

Refpiration is therefore, according to the theory of Davy, a chemical procefs—the combination of phos-oxygen with the venous blood in the lungs, and the liberation of carbonic acid and aqueous gas from it. From the combination and decompofition arifes an increafe of repulfive motion, which, combined with that produced by the other chemical proceffes taking place in the fyftem, and that generated by the reciprocal action of the folids and fluids, is the caufe of animal heat.

Dr. Menzier's attempt to

An attempt has been made by Dr. Menzies, or rather he informs us he has ventured to examine, how the

afcertainment of the quantity of air ufually refpired may throw light on the generation of animal heat, and on the quantity of heat generated in a given time; and he is of opinion, that this can be eftimated independently of any theory on the nature of heat itfelf. afcertain the quantity of animal heat generated in a given time.

The experiments of Crawford, Lavoifier, and de la Place, prove, when equal quantities of air are vitiated by refpiration and combuftion, that equal degrees of heat are evolved. Crawford found, that if an animal be fhut up in a veffel furrounded with water and protected from the accefs of air by very foft wool, one hundred meafures of air, each containing an ounce, vitiated either by this animal's refpiration or by the combuftion of wax or coal, communicated the following quantities of heat to 31 lbs. 7 oz. of water.

		Degrees.
100 meafures of air vitiated by	The combuftion of coal, gave	19.3
	———————— wax, ...	21.0
	The refpiration of a guinea pig, ...	17.3

But as each degree of Crawford's thermometer makes only one tenth of a degree of Fahrenheit's, it is evident, that, if a thoufand fuch meafures were vitiated by the combuftion of wax and the refpiration of a guinea-pig, the difference between the quantities of heat given out to 31 lbs. 7oz. of water will make 3.7 degrees of Fahrenheit's; the difference between the quantities given out by the combuftion of coal and the refpiration of a guinea-pig will be equal to 2 degrees of Fahrenheit's thermometer: *i. e.* the heat communicated to the water by the guinea-pig will be two degrees lefs than that communicated by the combuftion of coal.

But from the feries of experiments of Lavoifier and de la Place (Mémoire fur la Chaleur, 1783) it appears, that the heat communicated by the refpiration of a guinea-pig,

when equal quantities of air were vitiated, was greater than that generated by the combuftion of coal in the proportion of 13 to 10.3. But as contemporary authors have fuppofed the degree of heat faid to be communicated by the guinea-pig to be fomewhat exaggerated, and as the refult of their experiments was almoft the fame, Dr. Menzies thinks the average number may be taken as a rule—the difference probably proceeding from the different conftruction of the inftruments employed: hence it is conceived, that when equal quantities of air are vitiated, whether by refpiration or the combuftion of coal, nearly equal quantities of heat are generated.

As the quantity of heat generated when a given quantity of fixed air is produced by the combuftion of coal has been lately demonftrated by Lavoifier (Elements of Chemiftry, p. 101), and as the quantity of air ufually refpired has been afcertained: it is evident that the quantity of heat generated in the lungs, in any given time, could be alfo found out, if the quantity of fixed air was eftimated in the air that has been once breathed.

by eftimating the quantity of fixed air in refpired air. Firft experiment.

The following experiments were made with this view: A quantity of air once refpired was preffed out of an allantoid into a glafs bottle inverted in water; and, left any part of the fixed air fhould have been abforbed by the water, fome oil was previoufly poured into the bottle. The bottle was then inverted into another veffel filled with cauftic alkali. The barometer was in the mean time attended to, and the degree of heat marked by a thermometer. The air in the bottle was then fhaken, and left in contact with the cauftic alkali till all the fixed air was abforbed. Then the bottle was again plunged into the water, till the cauftic alkali in the bottle and the water in the veffel were at the fame height. The bottle being then ftopped with a cork, and placed on it's bottom, it contained a quantity of cauftic alkali, which, accurately

weighed, gave the quantity of fixed air abſorbed, after ſome corrections being made on account of the aſcent and deſcent of the mercury in the barometer, and the difference of temperature in the bottle.

Thus the bottle contained 2038.5 cubic inches; the temperature of the air of the bottle was 59° of Fahrenheit; the altitude of the mercury in the barometer was 29.07 inches. The temperature of the air, after two days, was 57.5°; the altitude of the mercury in the barometer was 29.37 inches; the cauſtic alkali of the bottle weighed 5 lbs. $9\frac{1}{2}$ oz., equal to 131.2713 cubic inches. But, on account of the aſcent of the barometer, it is neceſſary to ſubtract 2.09 cubic inches, and 6.471 cubic inches, becauſe the air in the bottle was rendered 1.5° (of Fahrenheit) colder: for as the volume of elaſtic fluids is in the inverſe proportion of the weight preſſing on them, $29.37 : 29.07 :: 2038.5 : x = 2017.6$: and $2038.5 - 2017.6 = 20.9$.

And as atmoſpheric air is expanded $\frac{1}{472.5}$ of it's volume for every degree of Fahrenheit's thermometer $\frac{2038.5}{472.5} \times 1.5° = 6.471$. So $131.2713 - 20.9 - 6.471 = 103.9$, the number of cubic inches of fixed air in 2038.5 inches of air once reſpired; a quantity leſs than one nineteenth of the whole; for $\frac{2038.5}{103.9} = 19.6$. But, leſt any part of the fixed air ſhould be abſorbed, oil was uſed inſtead of water.

The bottle was filled with air once reſpired and paſſed through oil: this bottle contained 179.812 cubic inches. Second experiment.

The thermometer and barometer were as in the laſt experiment. The cauſtic alkali, after two days, weighed $6\frac{1}{20}$ oz. and meaſured 11.451 cubic inches. But $29.37 : 29.07 :: 179.812 : x = 177.973$; and $179.812 - 177.973 = 1.839$; and $\frac{179.812}{472.5} \times 1.5° = 0.5707$.

Thus $11{,}451 - 1{,}839 - 0{,}5707 = 9{,}042$, the quantity of

fixed air in 179.8 cubic inches of air once refpired; for $\frac{179.812}{9.042} = 19.8$.

The fame experiment being repeated with the fame bottle, 3 oz. 1 dr. only of cauftic alkali, meafuring 5.9148 cubic inches, were found in the bottle. But as during this time the mercury in the bottle had fallen fix tenths of an inch, 3.817 cubic inches muft be added to that quantity. And as the air in the bottle was found eight tenths of a degree colder towards the end than at the beginning of the experiment, 0.3044 parts of an inch are to be fubtracted from it.

For $29.2 : 29.82 :: 179.812 : x = 183.629$; and $133.629 - 179.812 = 3.817$; and $\frac{179.8}{472.5} \times 0.8 = 0.3044$.

So that $5.9148 + 3,817 - 0.3044 = 9.427$. And $\frac{179.812}{9.427} = 19.07$.

In frequently repeating thefe experiments with the large and fmall bottles, whilft the ftate of the thermometer and barometer was carefully attended to, the greateft variation was 20.1 : fo that the average number will be 19.6.

Dr. Menzies likewife made fome experiments to difcover the quantity of fixed air in the room where thefe were made; but the quantity in 2038.5 cubic inches of air refpired was found to be fo fmall as to be fcarcely perceptible. If any calculation be attempted, the quantity of fixed air may be eftimated at $\frac{1}{20}$th or $\frac{5}{100}$dths of air once refpired.

Thus, if the quantity of air commonly infpired be eftimated at 40 cubic inches, and the number of refpirations at 18 in a minute, 720 cubic inches will be infpired in the fpace of a minute; of which quantity only $\frac{27}{100}$dths, or 194.4 cubic inches confift of vital air, the only conftituent of atmofpheric air changed by refpiration.

But 5 parts only of atmofpheric air are changed in each refpiration: hence 36 cubic inches of fixed air are generated in the fpace of a minute in the lungs of a middle-fized man, or 51840 cubic inches in the fpace of a day—a quantity of air weighing 22865.5 grs. or 3.9697 lbs. troy weight. And as Lavoifier has calculated that for every pound of fixed air generated by the combuftion of coal a quantity of heat is evolved which would melt 27.02024 lbs. of ice; and as the fame quantity of heat is generated in air vitiated either by refpiration or by the combuftion of coal; it follows that the quantity of air vitiated daily in the lungs of an ordinary man will give out nearly as much heat as would melt 107.2 lbs. of ice: for $27.02024 \times 3.9697 = 107.2622$. But as a portion of this heat is carried off in the air expired, under the form of fenfible heat; and as a portion is employed in the formation of vapour, or is rendered latent; thefe quantities can be calculated in the following manner:—

As a cubic inch of atmofpheric air weighs 0.32112 parts of a grain, 40 cubic inches will weigh 12.8448 grains. But $\frac{5}{100}$ parts of this quantity being converted into fixed air, if the whole remains free from moifture it will gain 0.19794: fo that it will weigh 13.04274 grains. Hence the air expired during the fpace of a minute will weigh 234.7693 grains; or that expired during a whole day will weigh 338067.82 grains, or 58.692 pounds. But if air of this kind be fuppofed to have the fame capacity for receiving heat as water, it follows that the fame degree of heat that would raife 58.69 lbs. of water fome degrees, would alfo raife the air to the fame degree. But the quantity of heat requifite to raife 58.69 lbs. of water to the 66th degree of Fahrenheit, is equal to that which would melt 27.6692 lbs. of ice; for fince 140 degrees of heat become latent in the formation of each pound of

water $\frac{58.69 \times 66^\circ}{140} = 27.6692$. Confequently the fame degree of heat will be daily evolved in the lungs under the form of fenfible heat.

The difcovery of latent heat fhows that a great quantity of heat is abforbed during the formation of vapour, without an increafe of temperature; and, according to the experiments of Watt, the heat thus abforbed, or rendered latent, would raife the temperature of a body of the fame fpecific gravity and capacity for heat as water, although it could not be converted into vapour, 960 degrees more than before.

Dr. Menzies weighed accurately a large allantoid, and then filled it with expired air. When it was quite cooled, and carefully weighed again, it was found to have gained two grains by every refpiration; which coincides with an experiment made by Hales, who found that fome moiftened diaphragms, through which he had breathed, gained fix grains in three minutes. Thus, if two grains of aqueous vapour be fubtracted every minute, without attending to what may be fubtracted for the difference between the weight of fixed and vital air, 6 oz. or 0.5 of a pound will be fubtracted daily. But if the temperature of a body incapable of being evaporated, of the fame capacity for heat as water, weighing 0.5, be increafed 960 degrees, this heat will diffolve 3.42854 lbs. of ice: for $\frac{960 \times 0.5}{140} = 3.4285$. But as Crawford computes the relative heat of aqueous vapours at 1.55, a quantity of heat will be fubtracted which would diffolve 1 lb. and 0.8856 hundredth parts of ice more than if it's capacity for heat had been the fame with that of water; or, in other words, all the heat daily confumed in the lungs, in forming aqueous vapour, would diffolve 5.3141 lbs. of ice. So that all the heat daily evolved in the lungs under the

form of ſenſible heat and vapour, would diſſolve 32.9833lbs. of ice. For 27.6692 + 5.3141 = 32.9833.

But as it was before demonſtrated, that in one day a quantity of heat was evolved by the change induced in the air in the lungs, which would diſſolve 107.2622 lbs. of ice.
Subtract thence 32.9833

There will remain 74.2789

which would be the quantity capable of being diſſolved by the heat daily evolved in the lungs of an ordinary man. But it is neceſſary the blood ſhould abſorb the heat, becauſe it is expoſed to it's action in the lungs for the ſpace of ſome hundreds of ſquare feet, and becauſe this fluid is admirably calculated to diffuſe heat through all the body. The degree to which the blood is heated in it's paſſage through the lungs, may, according to Dr. Menzies, be eſtimated in the following manner:—If the quantity of blood which paſſes through the lungs in the ſpace of a minute may be eſtimated at 8 lb.; if the heart be ſuppoſed to propel an ounce and a half in each ſyſtole; and if the blood be ſuppoſed to have an equal capacity for heat with water; it is evident that the quantity of heat that would make 8 lbs. of water riſe to any given point, would alſo make 8 lbs. of blood riſe to the ſame point. But as the quantity of heat abſorbed during a day by the blood has been ſhown to be ſufficient to diſſolve 74.27 lbs. of ice, the quantity abſorbed each minute could only diſſolve 0.05158 of a lb. of ice. Beſides, ſince 140° of heat are requiſite to liquefy 1 lb. of ice, or become latent, 1 : 140 :: 0.05158 : $x = 7.22°$, or the quantity of heat requiſite for diſſolving 0.05158 of a pound of ice would increaſe the temperature of a pound of water by 7.22°, or 8 lbs. by 0.90265 of a degree of the thermometer of Fahrenheit. Thus the heat generated each minute in the lungs of an ordinary man would raiſe the temperature of the blood paſſing

The degree to which the blood in the lungs is heated eſtimated.

through them in that ſpace of time, by 0.90265 of a degree, if blood had an equal capacity for heat with water. But as Crawford concludes that the comparative heat of venous blood bears the ſame proportion to that of water as 0.8928 to 1, it is evident that the ſame degree of heat which would raiſe venous blood one degree would raiſe the ſame quantity of water only 0.8928 of a degree; or that their temperatures are in the inverſe proportion of their capacities for heat.

Thus the quantity of heat would raiſe the ſame quantity of venous blood 1.01103°; for 0.8928 : 1.0000 : : 0.90265 : $\frac{0.90265 \times 1}{0.8928}$ = 1.01103. And as he found that the capacity of venous blood for heat is increaſed by it's becoming arterial, in the proportion of 0.8928 to 1.03; if venous blood is raiſed 1.01103° by the heat evolved in the lungs, it follows that arterial blood will be raiſed only 0.8763; for 1.03 : 0.8928 : : 1.01103 : x = 0.8763.

Thus 0.13468 parts of a degree of Fahrenheit's thermometer equal the quantity of heat which becomes latent, although the capacity of the blood for heat is increaſed in the ſame proportion; for 1.01103—0.87635 = 0.13468.

Therefore the blood in it's paſſage through the lungs, according to the calculation of Dr. Menzies, gains 1.01103, or more than one degree of Fahrenheit, and it's temperature is increaſed 0.8763 of a degree. Whence it follows, that the blood in the left ſide of the heart is warmer than that in the right by eight tenths of a degree. This ſeems to be confirmed by an experiment of Hunter's on a live dog; for, having introduced the ball of a thermometer two inches within the rectum, the quickſilver roſe to 100° and a half exactly. The cheſt of the dog was then opened, and a wound made in the left ventricle of the heart; and immediately on the ball being introduced the quickſilver roſe to 101° exactly. A wound

was next made ſome way into the ſubſtance of the liver, and the quickſilver roſe to 100° and three quarters. It was next put into the cavity of the ſtomach, where it ſtood at 101°. All theſe experiments were made in a few minutes.

Hence, according to Dr. Menzies, the quantity of animal heat generated in the lungs may be determined by a method founded on the two following propoſitions.

1. That nearly equal quantities of heat are evolved when equal quantities of vital air are vitiated, whether by the combuſtion of coal, or by the reſpiration of animals.

2. That the quantity of fixed air generated in the lungs in any given time, can be eaſily determined by knowing the quantity of fixed air in air once reſpired.

This method, therefore, has no connexion with any theory of animal heat, or with the different capacities of fixed and vital air for heat.

Different authors have given the heat of the human body. According to Boerhaave it's natural heat is 92° or at moſt 94°; and Pitcairn makes the heat of the ſkin to be the ſame. It is however evident, that the different parts of the body not only differ from each other, but that they differ from themſelves according to the ſeaſons and other circumſtances: hence the difference of the reſults amongſt phyſicians who have attempted to aſcertain the animal heat. Heat of the human body.

Amontons found it to be .... 91, 92, or 93°
Sir Iſaac Newton .... $95\frac{1}{2}$
Fahrenheit and Muſchenbroek found the blood to be 96
Dr. Martine found the ſkin to be ....97 or 98
———— ——— the urine 99
Dr. Hales found the ſkin 97
————— the urine 103
John Hunter under his tongue 97
———— in his rectum .... $98\frac{1}{2}$
———— in his urethra, at one inch 92

John Hunter in his urethra, at two inches . . . . 93°
———————————— at four inches 94
———————————— at the bulb of the urethra 97

Such are the phenomena refpiration produces in the more perfect animals with warm blood; and fuch have been the various opinions with refpect to the utility of this procefs, and the part it acts in the animal œconomy. The next part will give an account of the refpiration of fifhes and infects.

Experiments of Prieftley.

Refpiration of Fifhes.—Dr. Prieftley having found, according to the phlogiftic fyftem, that the principal ufe of the *lungs* and of the *blood* in man, quadrupeds, and animals with lungs, is to difcharge phlogifton from the animal fyftem, in a ftate proper to diminifh refpirable air, and to render it unfit for refpiration, was defirous of trying whether fifhes, which do not breathe like other animals, part with phlogifton to the water in which they live. With this view he put two (a large perch and an eel) into a pail of water; and when they had been in it about twenty-four hours he nearly filled a large phial with the water, and in it he agitated a fmall quantity of common air between fix and feven minutes, and found that it was confiderably injured by the operation; for two meafures of this and one of nitrous air occupied at firft the fpace of two meafures and one fixth, and by ftanding feveral days were never lefs than two meafures. But when he agitated an equal quantity of air in the fame quantity of the fame water in which no fifhes had been confined, and for the fame fpace of time, it was not injured in the flighteft degree. It is evident, therefore, according to Prieftley, that phlogifton is difcharged from fifhes as well as from other animals; that this phlogifton affects the water, and this water the air that is agitated in it; and in the fame manner as the fifhes themfelves would have affected it, if it had been poffible for them to breathe it. Other experiments

confirmed and extended thefe conclufions. Having filled a phial with fome water from the hot well at Briftol, which he found to contain air in a great ftate of purity, he put a few minnows and other fmall fifhes into it, about two inches in length, and confined them without any accefs of common air until they died. He then took equal quantities of the foul and of frefh water, and expelled from both all the air they would yield. That from the water in which no fifhes had been put, or the frefh, exceeded the foul in the proportion of three to two; and by the teft of nitrous air, the former exceeded the latter in a ftill greater proportion. The frefh was about the ftandard of common air, and the foul fomewhat worfe than air in which a candle juft goes out: it might have been worfe, but the water remained in an open veffel all night before the experiment. Hence, air contained in water in an unelaftic ftate is as neceffary to the life of fifhes, as air in an elaftic ftate is to that of land animals.

He then had no doubt but that putting fifhes into water impregnated with air thoroughly phlogifticated would be equally injurious to them, as this air in an elaftic ftate is to land animals; and this was verified. He began with rain water which contained no air, having been recently boiled. He put nine fmall fifhes into a veffel containing about three pints of it, and they lived between three and four hours, no air having been admitted. Two fifhes were put into a pint of it impregnated with phlogifton from air that had been phlogifticated fix months before by means of iron filings and fulphur, and they lived in it nearly an hour. It was very imperfectly impregnated. Inflammable air had a fimilar effect. John Hunter having informed him that fifhes would not live in water impregnated with fixed air, he tried it, and found that fmall fifhes would not live in it more that a few minutes. It is well known that all fpa waters containing fixed air are fatal to fifhes, frogs, and

infects. He found that in water impregnated with nitrous air they were affected in the fame manner, but more violently; but as a decompofition of fome fmall part of the nitrous air might take place before he could poffibly flip the funnel into the neck of the phial, he introduced the fifhes into the veffel in which he had impregnated the water while it remained inverted in the bafin, the remainder of the nitrous air not imbibed by the water ftill refting upon it. The phial contained fomething more that a pint, and the nitrous air occupied about one fourth of it. Into this veffel he introduced two fmall fifhes, and they continued very quiet, without being feized with any convulfions (as happened before), ten minutes, or a quarter of an hour, before they died. Hence, the caufe of the convulfions, in the former experiment, arofe not from the *nitrous air*, properly fpeaking, but *nitrous acid*, which acted like the fixed air, another kind of acid. Whereas now the fifhes were no otherwife affected than in water with phlogifticated or inflammable air, except that the water had imbibed more of the nitrous air, and hence was fooner fatal to them.

Brouffonet. From the conformation of the organs of refpiration, or the gills, in thefe animals, Brouffonet has formed them into two divifions: *viz.* the cartilaginous, fuch as the fea-dog, the fhark; and the fpinous, as the fea-wolf, &c. In the firft divifion, the gills are fuftained by a cartilaginous arch, and are more confiderable in number than in the fecond; in the laft, they are fupported by feveral fmall curved bones, the number being feldom lefs than four, and never exceeding it.

The ftructure of the gills is fo formed, that the fanguineous veffels, which are diftributed over them, make, as in the lungs of quadrupeds, a very long paffage in a fhort fpace; but they differ very much in different kinds of fifhes. The way of life to which nature has deftined

thefe animals is the principal caufe of thefe varieties, which rarely take place in the refpiratory organs of different quadrupeds and birds. Thus fifhes which live in ftill water and in places where the water is rarely renewed, fuch as eels, have their gills fuftained by fhort offeous arches; the cavity of their gills is very large, and they are able to preferve the water in thefe organs a much longer time than other fifhes. They may in fome meafure be compared to the reptiles and oviparous quadrupeds, which have cellular lungs furnifhed with fibres, and in fuch a manner as to be able to keep a certain quantity of air in referve in cafe of need. On the contrary, in thofe fpecies of fifhes that frequent the high feas, and are deftined to make long emigrations, and fwim very rapidly, the gills are placed upon very great bones; feveral are provided with a peculiar organ, deftined like the gills for refpiration.

In animals that refpire air there is only one aperture by which this element is received and rejected: this is not the cafe in fifhes which receive water into their refpiratory organs by different ways: thus, in the lamprey there is only one opening at the fummit of the head, by which the water is conducted to the gills; in the ray there is one on each fide of the head; whilft the greater number of fifhes receive water by their mouth, and it departs by the gills. In the cartilaginous fifhes, whofe organs of refpiration, as has been obferved, are more extenfive than thofe of other fifhes, the greateft part reject the water by feveral openings; as in the lampreys, which have feven holes; the fea-dog has five, and the fturgeon has only one, forming feveral divifions. The other fpecies of fifhes have only one opening, but it's form varies according to the animal œconomy of each kind. Thus, thofe deftined to live in fhallow waters and never at a diftance from the banks, and fometimes buried in the fand, have this opening very fmall,

forming a ſpecies of canal ſurrounded by thick membranes. Thoſe which are obliged to make rapid motions have their gills, on the contrary, the moſt extenſively formed; their mouth and the opening of the gills are very large; they receive a great quantity of water, and renew it much oftener than the others; they die almoſt as ſoon as they are out of the water: whilſt carp, eels, &c. which have ſmall openings, live a long time in the open air. On comparing the reſpiration of fiſhes with that of animals that breathe in the open air, it appears, that the firſt more frequently inſpire than the laſt; becauſe the oxygen to be extracted from the water is much leſs abundant than in the atmoſphere, and it is more difficultly ſeparated from the water. Fiſhes, however, appear to have the advantage of a reſervoir, which ſerves occaſionally to ſupply the deficiency of oxygen by the reſpiratory organs. This is called the air-bladder of fiſhes. According to the experiments on the air which this bladder contains, by Brodbelt of Jamaica, particularly that of the ſword-fiſh, it is pure oxygen gas; he thinks it ſerves the purpoſes of life when the animal is unable to come to the ſurface. Accum ſays the air-bladder of a carp contains common air. Monro had ſuppoſed it to contain fixed air. Fourcroy ſays it is azot gas united ſometimes with a little carbonic acid gas; that it is produced in the ſtomach, and thence paſſes into this airy *receptacle*. Fiſhes are not able to ſupport in water a degree of heat equal to that which man and quadrupeds ſupport in the atmoſphere, and the difference is very conſiderable. On making the compariſon, phyſicians have obſerved, that air may be breathed by the human ſpecies at 264° with impunity. Tillet made animals breathe an air heated to 300°. A girl, likewiſe, under Marantin, breathed an air of 325° for five minutes. Notwithſtanding ſuch degrees of heat would be inſupportable to fiſhes, and would even be ſufficient to

Air-bladder of fiſhes.

deſtroy their organization, ſeveral obſervations have been made on fiſhes found alive in very warm waters, and even by the ancients. Thus Ælian ſpeaks of a lake in Libya, the water of which is very warm, and fiſhes are found in it which die if tranſported to a colder water. Similar obſervations are to be found in St. Auguſtin and Cardanus. Shaw, in his voyage to Barbary, ſpeaks of ſeveral hot waters in which he had found ſeveral ſpecies of perch; and des Fontaines lately made the ſame obſervation in the neighbourhood of Cafza, where the thermometer of R. roſe to 30°. Lucas, in his Hiſtory of Mineral Waters, gives ſome obſervations on living carp found in a thermal water, the heat of which was equal to that of the human blood. Valiſnieri and Conringius have likewiſe ſeen living fiſhes in thermal waters. Anderſon witneſſed a ſimilar fact in Iceland. But the moſt ſurpriſing fact is that of Sonneret, who found ſome fiſhes in a water at the Manillas at the degree of 69 of Reaumur. From the experiments of Brouſſonet, fiſhes did not live at ſo high a temperature. Muſchenbroek had already found that fiſhes periſhed at 111° of Fahrenheit; he even ſaw a very vigorous perch die in three minutes in a water heated to 96°. He adds, that theſe animals lived very well at 72°. It is very difficult to determine, in a poſitive manner, the different degrees of heat each ſpecies is able to bear; they differ not only according to the ſeaſon, but likewiſe according to the forms of the organs of reſpiration.

On the 20th of June, 1784, Brouſſonet put a couple of ten-ſpined ſtickle-backs (epinoches) into ſome water at a temperature of 14°. This was gradually heated, and at the end of two hours and a half the thermometer mounted to 28°: the fiſhes then became agitated, but on being caſt into freſh water they became well again in a few minutes.

On the 10th of November, 1784, he put a carp, ſome bleaks, gudgeons, and perch, into ſome water of the Seine

at 5°, and the bottom of the veffel was covered with fand. At 25 minutes paft twelve o'clock the thermometer was at $6\frac{1}{2}$°; at 30 minutes at 8°, &c. This experiment lafted till 45 minutes paft four; and he marked the degrees of heat every five minntes, pouring fome frefh water into the veffel at different times in fmall quantities. At 12°, the fmalleft fifhes began to rife to the furface of the water, became agitated and ill; yet the Seine water is much warmer in the fummer. At 21° the fmall bleaks were nearly dead. At 22° the perch were motionlefs, and reverfed. The gudgeons, which were of a larger fize, did not appear to fuffer till 23°; whilft the carp was not at all agitated, it's refpiration being only more frequent. At 28°, at which point the water was kept 15 minutes, the carp began to lofe it's equilibrium, and became ill; it afterwards appeared dead, and only came to itfelf again after being left a long time in frefh water. Brouffonet employed four hours and a half in bringing the heat of the water to 28°. He is of opinion that, with certain precautions, fifh would live in a water heated beyond 28°.

"On fuppofing," fays Brouffonet, "as I have reafon "to believe from my experiments, that fifhes cannot fup-"port water heated beyond 30°; on recollecting, at the "fame time, that it is impoffible for them to live in a wa-"ter the temperature of which is a few degrees below zero, "it would follow that thefe animals could only live in a "fcale of 30 degrees at moft; a fcale which, when com-"pared with that fupported by warm-blooded animals, "will appear very fhort: it will, however, always be in "a ratio to the vital heat, which in fifhes is even below "that of reptiles and oviparous quadrupeds. Martine has "obferved of feveral falt-water fifhes, that the heat of "their blood did not exceed the water in which they "were, more than one degree. The fame experiment re-

"repeated upon a trout, and other river-fiſh, afforded him "the ſame reſult. Mr. John Hunter ſaw the thermometer in the ſtomach of a carp riſe from $65\frac{1}{2}°$, which was "the temperature of the water, to 69°, i. e. three degrees "and a half higher: but it is neceſſary to obſerve that "the fiſh was then out of the water; which muſt have a "great influence on the reſult of the experiment."

Brouſſonet plunged a thermometer into the bodies of ſeveral ſmall fiſhes of the Seine, which never roſe higher than three fourths of a degree beyond the temperature of the water; ſometimes it only increaſed half a degree, particularly in thoſe that were ill. A pretty large eel, although weak, only cauſed the thermometer to riſe three fourths of a degree. Carp conſtantly gave one degree more, ſome a degree and a half; ſo that it appears the animal heat of fiſhes is very inconſiderable.

According to the ſame author, fiſhes are ſubject to a great loſs of animal heat by the water continually extracting it; ſo that the portion of this fluid immediately ſurrounding them is warmer than elſewhere. It has been obſerved, that a carp plunged into a mixture that ſoon became congealed, preſerved around it a certain quantity of fluid water, although the reſt was totally congealed.

The animal heat of fiſhes, no doubt, ariſes from their reſpiration; for the phenomena by which Lavoiſier and de la Place have explained it's production in animals living in the atmoſphere, are obſerved alſo in fiſhes, but in a leſs evident degree: the difference of heat between animals breathing air, and thoſe which reſpire water, is more particularly remarkable on comparing fiſhes with the cetaceous order. Both inhabit the ſame element; yet thoſe with gills, that reſpire water, have only one degree or one and a half more than the water itſelf, whilſt the cetaceous order that reſpire air have their blood as warm as man. Brouſſonet found the body of a porpoiſe

juſt dead to be $28\frac{1}{2}°$ in the neck, whilſt the temperature of the atmoſphere was at $14°$, and that of the ſea-water near the ſhore at $13\frac{1}{2}°$.

It alſo appears that fiſhes do not ſuffer ſuch extreme variations of cold and heat as quadrupeds. The temperature of the water, at a certain depth, is almoſt always the ſame, as appears, with reſpect to the ſea, from the experiments of Marſili and Sauſſure. That of rivers, when the ſurface is frozen, is a few degrees above zero in the middle. In great heats, the temperature of the water is always below that of the air.* Yet it appears that theſe animals are more ſenſible to a great degree of heat than of cold.

Fiſhes are, however, affected by the variations of the atmoſphere; and it is to it's great variations in temperature that the emigration of that prodigious quantity of herrings is to be attributed, which the cold of the pole forces annually to ſeek more temperate ſeas. Fiſhes likewiſe which live near the banks, feel the cold of the air, and go into deeper places to protect them from it, where the greater part remain in a ſtate of torpidity, ſimilar to what bears, marmots, and dormice undergo during the winter. The ancients have given ſome account of this periodical ſleep, whilſt the moderns have ſcarcely obſerved it. The fiſhes of this order may be, however, known by the great length of their body, the abſence of the ventral fins, and the undulating motions they are obliged to make to ſupport themſelves in the water.

It is obſerved that water affects the organs of reſpiration in fiſhes, in a greater variety of ways than air acts upon thoſe of warm-blooded animals. Several individuals, after having reſpired a certain quantity of water for ſome time, vitiate it ſo much as to be no longer proper for reſpiration, in the ſame manner as warm-blooded animals change the air. Water, likewiſe, holds in ſolution a

greater number of fubftances than the air; and amongft thefe many are found to be prejudicial to fifhes, by acting on their refpiratory organs, which more rarely happens to animals living in the atmofphere. They are able, however, to refift fome of thefe changes: thus, they pafs from falt to fweet waters, and reciprocally, without detriment; numbers of falmon, fhads, lampreys, &c. annually leave the fea and mount the frefh water rivers, whilft the carp often quits the river for the faltnefs of the ocean. Brouffonet found that fifhes are able to live in diftilled water; that they at firft fhowed figns of uneafinefs, but after fwimming about for fome time they no longer appeared to fuffer; he thinks it moft probable, that by moving about they had caufed the water to unite with a quantity of air fufficient for refpiration. He, however, found that a fmall fifh enclofed in a corked bottle containing a pint of diftilled water, lived more than thirty hours. He found that a fmall quantity of firup of violets, dropped into the diftilled water in which were living fifhes, at firft underwent no change of colour: it became fomewhat green afterwards, arifing perhaps from the alkali of the mucus with which they are covered, and which always mixes with the water. A drop of acid of arfenic in a large quantity of water immediately killed a very ftrong fifh. Water flightly impregnated with fixed air deftroyed a fimilar fifh in a few minutes. Plunged into lime water they likewife very foon died. It was well known that by throwing lime into water fifhermen are accuftomed to deftroy the fifhes; and by feveral other fubftances the fame is effected. Thus, in the Indies the juices of feveral fpecies of plants are made ufe of. In the fouth of France the milky juice of the *euphorbia characias* of Linnæus, which grows there in great abundance in uncultivated places, is employed for the fame purpofe. It is by affecting the

refpiratory organs of thefe animals that their death is occafioned.

Bell. We are informed by Bell (in contradiction to what Brouffonet has faid), that if there be no air in the water in which fifhes are, or not in fufficient quantity for them to breathe, they die; that diftilled water is to thefe animals what the vacuum of an air-pump is to an animal that refpires air in the atmofphere; that if you exhauft water of it's air by a pump, or boil or diftil it, or by any other means deprive it of it's air, fifhes are no longer able to breathe in it; that they rife to the furface and gafp for air; and that on extracting the air from water in which fifhes have refpired, it is found to be contaminated exactly in the fame manner as air refpired by warm-blooded animals; and that it differs very little from that in which a candle has fpontaneoufly become extinguifhed; which, according to this author, are fufficient facts to prove that the gills of thefe animals perform the fame functions of a real refpiration as the lungs of a man and quadrupeds, which extract the oxygen from the atmofphere.

Davy. For more fatisfactory information refpecting the refpiration of fifhes, we are indebted to Davy; for, as it has been fuppofed that fifhes decompofe both water and oxygen gas, he made the following experiments to afcertain the truth.

1ft Experiment. He expelled, by long boiling, the atmofpheric air from 64 cubic inches of fea-water: he then excluded it from the air by means of mercury. Having then introduced a fmall mullet, it was inftantly convulfed, and died in a few minutes.

2d Experiment. A quantity of water was freed, by boiling, of it's atmofpheric air: two receivers, each of the capacity of 36 cubic inches, were filled with this water: into one of thefe two cubic inches of nitrogen

were introduced, into the other two of phos-oxygen. By long and conſtant agitation the gaſes were diſſolved by the water, which was excluded from the contact of air by mercury. Into each of the receivers two minnows were introduced. Thoſe in the water holding nitrogen in ſolution died in about four minutes, thoſe in the water holding phos-oxygen, in ſolution appeared totally uninjured, and when examined, after ſome hours, were ſtill alive and healthy.

3d Experiment. The ſame receivers uſed in the laſt experiment were filled with diſtilled water freed from atmoſpheric air by a ſecond boiling. Into each of theſe, three cubic inches of phos-oxygen were introduced. The receivers were then agitated for ſome time, till the water in each of them had diſſolved an equal quantity of gas; they were then inverted in a trough of mercury, ſo as to exclude atmoſpheric air from them. Four minnows were then conveyed into one of them through mercury. The receivers were now ſuffered to remain untouched for ſix hours, when they were examined. The minnows were alive, and no gas remained in the top of the receiver in which they had reſpired. The gas in the top of the other receiver remained nearly the ſame as at the commencement of the experiment. A quantity of lime-water was poured into each of theſe receivers; in that in which the fiſhes had exiſted there was a very perceptible cloudineſs, occaſioned, as Davy ſuppoſed, by the formation of carbonat of lime; in the other there was no perceptible change.

From theſe experiments Davy concludes, that the venous blood in the gills of fiſhes is phos-oxydated by the phos-oxygen held in ſolution by water; and that carbonic acid, and probably water, are given out as excrementitious by the venous blood in their gills. With reſpect to the decompoſition of water by fiſhes in reſpiration, as there is

no evidence of hydrogen being formed, there can be no reafon for the fuppofition.

Refpiration of Infects.—From the much greater length of time infects are capable of exifting than other animals in carbonic acid gas, and, according to Dr. Prieftley, in air infected by putrid effluvia, it had been fuppofed by fome phyfiologifts that this clafs of animals either had the power of living a certain time without breathing, or that they had not the fame occafion for it as others whofe refpiration is well underftood. It had not been confidered, that as infects, from their habits of life, are accuftomed to live in places where the air is in a ftate of great impurity, they would not be fo liable to experience it's bad effects, as thofe who conftantly breathe a purer atmofphere: nor was it well underftood by what means this function was carried on in this moft numerous part of the animal kingdom.

Scheele and Bergman. It was, indeed, a fact acknowledged by Scheele and Bergman, that infects, the fame as other animals, converted vital air into mephitic gas by the act of refpiration; but no experiments of any confequence had taken place on this fubject before thofe of Vauquelin, at leaft they were by no means fo fatisfactory. It is now well known that the function of refpiration is not performed by the mouth of infects, by which they differ very much from warm-blooded animals, and that they have not like them a pulmonary organ into which the blood paffes to receive the influence of the air from the atmofphere.

It is now well underftood, that infects take in this element by means of certain openings or holes, to which entomologifts have given the name of ftigmata, from their refemblance to fo many fpots on the furface of their body. Thefe ftigmata are of various forms; fometimes they are round, fometimes oval, but in general they are lengthened

like a button-hole. With refpect to the number, it varies according to the nature and fize of the animal.

The experiments of Vauquelin were made on the grafs-hopper (gryllus viridiffimus), the red flug (limax flavus), and the fnail (helix pomalia of Linnæus). The *grafs-hopper* has 24 ftigmata difpofed in four rows, parallel and exterior to the two white lines placed longitudinally on the middle of it's belly, and the motions of infpiration and expiration are well marked. Vauquelin found that this animal died immediately on being put into fulphureous hydrogenous gas. In fix cubic inches of pure air it exifted 18 hours, and in eight of common air 36 hours: he found that oxygen gas was indifpenfably neceffary to the life of this infect; that as foon as there no longer remains any or very little of this gas in the atmofpheric air, it immediately dies. The atmofpheric air in which feveral had died was found to contain fcarcely any remnant of oxygen gas: but whatever number were fuffered to breathe until their complete afphixy, it was not obferved that they had entirely converted the vital air into carbonic acid; they appeared conftantly to die before this conver-fion was complete. He attributes this to the fenfibility of the animal for the carbonic acid gas, which deftroys it when in large proportion as well as azot gas. Vauquelin.

The refpiratory organs of the *red flug* have not as yet been difcovered by anatomifts; but Vauquelin looks upon them to be the lateral openings of this animal, which are feen to dilate and contract. This flug, on being put into 12 cubic inches of atmofpherical air, died in 48 hours; and not the leaft appearance of oxygen gas was found afterwards, the remaining air precipitating lime water; which proves that it was entirely converted into fixed air. This chemift was much aftonifhed to find how completely this animal had analyfed the atmofpherical air, having never difcovered the leaft trace of vital air in the refiduum

of that refpired, when examined by means of phofphorus. "Hence," fays he, "it appears that worms have in their "refpiratory organs a great power of feparating the "oxygen gas from the particles of azot gas with which "it is on all fides furrounded, and that they have no oc-"cafion for a large quantity of oxygen at one time; that "they are able to remain for fome time without refpi-"ring in the ordinary way; and, thirdly, that they are "not very fenfible to the influence of carbonic acid gas "formed in the refpired atmofpherical air, and of the azot "gas left naked." A flug confumed in 48 hours 3.36 inches of oxygen gas, when it immediately rolled itfelf up, emitting from all parts a milky liquor, and died.

In fulphureous hydrogenous gas a flug fhowed no figns of life in about half an hour; which proves that worms cannot exift in an elaftic fluid containing no oxygen gas, although of all animals they appear from their manners of life to have the leaft occafion for it.

With refpect to the laft animal, the *fnail*, it lived four days in 12 cubic inches of atmofpherical air. The oxygen of this air was found to be entirely abforbed, or deprived of it's natural principle; for the azot gas remaining did not contain an atom of it, the refiduum likewife contained carbonic acid. That the death of this animal was owing to the want of oxygen, and not to the want of food, he proved by finding that others of the fame fpecies were able to live feveral months without any food.

From thefe experiments it appears,

1ft. That infects and worms refpire oxygen gas like warm blooded animals, and that like them they convert it into water and carbonic acid.

2d. That this principle is abfolutely neceffary in their refpiration, and that they die when deprived of it.

3d. That every other elaftic fluid, except oxygen gas, is unfit for their refpiration.

4th. That worms, and particularly the red flug and the efculent fnail, appear to have very extraordinary refpiratory powers, and very little fenfibility for the prefence of carbonic acid, fince they feparate all the vital air from the azot gas, and from the carbonic acid which is formed; and that they only perifh when there no longer remains any oxygen gas.

5th. That this property, Vauquelin thinks, may render thefe laft animals very ufeful as an eudiometer, by offering a proper means of exactly feparating the oxygen gas from the azot gas, and confequently of affording a perfect knowledge of the proportions of the principles of the atmofpherical air, or of a vital air, the degree of purity of which may be required.

Davy has difcovered, by experiments fimilar to thofe made upon fifhes, that the zoophytes have their refpiration governed by fimilar laws; that they, like fifhes, abforb the phos-oxygen held in folution by water, as well as portions of nitrogen; and thus, in their chemical attractions as well as in their organic powers, they feem to form the connecting links between animals and vegetables. Davy.

There now remains to give an account of the experiments and conclufions of this laft author on the nitrous oxyd, and fome other gafes, which he made upon himfelf and various animals, forming a curious mafs of information.

This ingenious experimentalift begins by explaining the word *refpirable*; which term he employs to denote thofe gafes capable of being taken into the lungs by voluntary efforts. On the contrary, *nonrefpirable* gafes, when applied to the external organs of refpiration, ftimulate the mufcles of the epiglottis in fuch a way, as to keep it perfectly clofe on the glottis, which prevents the fmalleft

particle of gas from entering into the bronchia, in ſpite of voluntary exertions. One only has the power of uniformly ſupporting life—atmoſpheric air. Other gaſes, when reſpired, ſooner or later produce death, but in different modes. Some, as nitrogen and hydrogen, effect no poſitive change in the venous blood. Animals immerſed in theſe gaſes die of a diſeaſe produced by privation of atmoſpheric air, analogous to that occaſioned by their ſubmerſion in water or nonreſpirable gaſes. Others, as the different varieties of hydrocarbonat, deſtroy life by producing ſome poſitive change in the blood, which probably immediately renders it incapable of ſupplying the nervous and muſcular fibres with principles eſſential to ſenſibility and irritability. Oxygen, which is capable of being reſpired for a much greater length of time than any other gas, except common air, finally deſtroy life; firſt producing changes in the blood, connected with new living action.

In making his experiments, Davy made uſe of a large mercurial air-holder, the invention of Clayfield: in it's form it is analogous to Watt's hydraulic bellows, conſiſting of a glaſs bell playing under the preſſure of the atmoſphere, in a ſpace between two cylinders filled with mercury. The inſtrument was graduated to the cubic inch of Everard, and furniſhed with a ſtop-cock.

To aſcertain the changes effected by reſpiration, the ſtop-cock having a very large orifice, curved and flattened at it's upper extremity, formed an air-tight mouth-piece. By accurately cloſing the noſe, and bringing the lips tight on this mouth-piece, after a few trials, he was able to breathe oxygen or common air for two minutes or two minutes and a half, without any other uneaſy feeling than that produced by the inclination of the neck and cheſt towards the cylinder: but the power of uniformly exhauſting the lungs and fauces to the ſame extent, required a

longer time. At laſt, by preſerving exactly the ſame poſture, after exhauſtion of the lungs before the inſpiration of the gas to be experimented upon, and during it's complete expiration, he found he could always retain nearly the ſame quantity of gas in the bronchial veſſels and fauces, the difference in the volume expired at different times never amounting to a cubic inch and half.

By connecting the conducting pipe of the air holder, during the reſpiration of the gas, with a ſmall trough of mercury by means of a curved tube, it became a perfect and excellent breathing machine: for, by exerting a certain preſſure on the air holding cylinder, it was eaſy to throw a quantity of gas, after every inſpiration or expiration, into tubes filled with mercury ſtanding in the trough. In theſe tubes it could be accurately analyſed, and thus the changes taking place at different periods of the proceſs aſcertained.

Davy was firſt induced to the examination of this gas, or the dephlogiſticated nitrous gas of Dr. Prieſtley, from Mitchill's Theory of Contagion, which is looked upon by the experimentaliſt as fallacious. In 1799 he began the inveſtigation: but a conſiderable time elapſed before he was able to procure the gas in a ſtate of purity, and his firſt experiments were made on the mixtures of nitrous oxyd, nitrogen, and nitrous gas, which are produced during metallic ſolutions. Dr. Mitchill attempted to prove that this gas, which he calls oxyd of ſepton, is the principle of contagion (*vide* art. Miaſmata), and capable of producing the moſt terrible effects when reſpired by animals in the minuteſt quantities, or even when applied to the ſkin or muſcular fibre. Davy, however, on making a few coarſe experiments on ſmall quantities of the gas procured from zinc and diluted nitrous acid, found that wounds were expoſed to it's action, and the bodies of animals immerſed in it, without injury; and that he was Nitrous oxyd.

able to breathe it, but with remarkable effects. He often breathed a quart of it, or even two quarts, mingled with more than equal parts of oxygen or common air In the moſt deciſive of theſe trials, it's effects appeared to be depreſſing, and he imagined it produced a tendency to fainting; the pulſe was rendered ſlower under it's operation. He then inſpired the pure gas; and as it paſſed through the bronchia without ſtimulating the glottis, and produced no uneaſy feeling in the lungs, it proved the nitrous oxyd to be reſpirable.

Method of procuring it.

The pure nitrous oxyd was procured by the decompoſition of nitrat of ammonia, in a temperature not exceeding 440°. 200 grains of compact nitrat of ammonia were introduced into a glaſs retort, and decompoſed ſlowly by the heat of a ſpirit lamp. The firſt portions were rejected, and the laſt received in jars containing mercury. This gas, when collected, exhibited the following properties:

It's properties.

a. A candle burnt in it with a brilliant flame and crackling noiſe. Before it's extinction, the white inner flame became ſurrounded with an exterior blue one.

b. Phoſphorus introduced into it in a ſtate of inflammation burnt with infinitely greater vividneſs than before.

c. Sulphur introduced into it when burning with a feeble blue flame, was inſtantly extinguiſhed; but when in a ſtate of active inflammation (i. e. forming ſulphuric acid) it burnt with a beautiful and vivid roſe coloured flame.

d. Inflamed charcoal deprived of hydrogen introduced into it, burnt with much greater vividneſs than in the atmoſphere.

e. Iron burned with great vividneſs, and threw out bright ſparks as in oxygen.

f. Thirty meaſures of it expoſed to water previouſly

boiled was rapidly abforbed: when the diminution was complete, rather more than a meafure remained.

g. Pure water faturated with it gave it out again on ebullition, and the gas thus produced retained all it's former properties.

h. It was abforbed by red cabbage juice, but no alteration of colour took place.

i. It's tafte was diftinctly fweet, and it's odour flight, but agreeable.

j. It underwent no diminution when mingled with oxygen or nitrous gas.

After the abforption of the nitrous oxyd by water, there remained another gas; on examining which it appeared reafonable to conclude,

1ft. That the refidual gas of nitrous oxyd is air previoufly contained in the water (which in no cafe can be perfectly freed from it by ebullition), and liberated by the ftronger attraction of that fluid for nitrous oxyd.

2d. That nitrat of ammonia at temperatures below 440° is decompounded into pure nitrous oxyd and fluid.

3d. That in afcertaining the purity of nitrous oxyd from it's abforption by water, corrections ought to be made for the quantity of gas difpelled from the water; this quantity in common water diftilled under mercury being about $\frac{1}{50}$th; in water fimply boiled and ufed when hot about $\frac{1}{36}$th, and in common fpring water $\frac{1}{12}$th.

It's fpecific gravity; accounting for the fmall quantity of common air contained in it (90 cubic inches of it containing about $\frac{1}{35}$th of common air, introduced from the mercurial air holder into an exhaufted globe, which increafed it in weight 44.75 grains, the thermometer being 50° and atmofpheric preffure 30.7); was concluded to be fuch, that 100 cubic inches weigh 50.1 grains at temperature 50°, and at atmofpheric preffure 37. It's fpecific gravity.

Compofition. It is compofed of oxygen and nitrogen; for, drawing conclufions from the quantity of carbonic acid formed, 2.5 grains of nitrous oxyd are compofed of .82 oxygen, and 1.68 nitrogen; or 100 grains of nitrous oxyd contain 37 of oxygen, and 63 of nitrogen. On making experiments on the refpiration of nitrous oxyd by warm blooded animals, it was procured as above related, and received in large jars filled with water previoufly faturated with the gas. The animal was introduced into the jar by being carried under the water, by which it fuffers little or nothing: after it's introduction, the jar was made to reft on a fhelf about half an inch below the furface of the water, and the animal carefully fupported fo as to prevent it's mouth from refting in the water. The animals experimented upon were the cat, dog, rabbit, guinea pig, moufe, and goldfinch.

Refpired by warm-blooded animals.

In each of thefe experiments a certain abforption of the gas was always perceived, the water rifing in the jar during the refpiration of the animal. From thefe it appears,

It's effects.

1ft. That nitrous oxyd is deftructive, when refpired for a certain time, to the warm blooded animals, apparently previoufly exciting them to a great extent.

2d. That when it's operation is ftopped before complete exhauftion is brought on, the healthy living action is capable of being gradually reproduced, by enabling the animal to refpire atmofpheric air.

3d. Exhauftion and death are produced in the fmall animals by nitrous oxyd fooner than in the larger ones, and in young animals of the fame fpecies, in a fhorter time than in old ones.

He found that animals live at leaft twice as long in nitrous oxyd as they do in hydrogen or water; confequently, there was every reafon to fuppofe from this circumftance

alone, that their death in nitrous oxyd could not depend on the ſimple privation of atmoſpheric air: but that it was owing to ſome peculiar changes effected in the blood by the gas.

The external appearance of animals that have been deſtroyed in nitrous oxyd is very little different from that of thoſe killed by privation of atmoſpheric air. The fauces and tongue appear of a dark red, and the eyes are dull and a little protruded. Their internal organs, however, exhibit a very peculiar change: the lungs are a pale brown red, and covered here and there with purple ſpots; the liver is of a very bright red, and the muſcular fibre in general dark. Both the auricles and ventricles of the heart are filled with blood. The auricles contract for minutes after the death of the animal. The blood in the left ventricle and the aorta is of a tinge between purple and red, whilſt that in the right ventricle is of a dark colour, rather more purple than the venous blood. Theſe appearances are ſimilar to thoſe obſerved by Dr. Beddoes in animals that had been made to breathe oxygen a great length of time. On diſſection.

From other experiments on the reſpiration of mixtures of nitrous oxyd and other gaſes, and on recapitulating thoſe before mentioned, it appears,

1. That warm blooded animals die in nitrous oxyd infinitely ſooner than in common air or oxygen; but not nearly in ſo ſhort a time as in gaſes incapable of effecting poſitive changes in the venous blood, or in nonreſpirable gaſes. Recapitulation.

2. The larger animals live longer in nitrous oxyd than the ſmaller ones, and young animals die in it ſooner than old ones of the ſame ſpecies.

3. When animals, after breathing nitrous oxyd, are removed from it before complete exhauſtion has taken

place, they are capable of being reftored to health under the action of atmofpheric air.

4. Peculiar changes are effected in the organs of animals by the refpiration of nitrous oxyd. In animals deftroyed by it, the arterial blood is purple red, the lungs are covered with purple fpots, both the hollow and compact mufcles are *apparently* very irritable, and the brain is dark coloured.

5. Animals are deftroyed by the refpiration of mixtures of nitrous oxyd and hydrogen, nearly in the fame time as by pure nitrous oxyd: they are capable of living for a great length of time in nitrous oxyd, mingled with very minute quantities of oxygen or common air.

Amphibious animals.

As it appeared that the nitrous oxyd deftroyed warm blooded animals, by increafing the living action of their organs to fuch an extent as finally to exhauft their irritability and fenfibility; it was reafonable to conjecture that the cold blooded animals, poffeffed of voluntary power over refpiration, would fo regulate the quantity of nitrous oxyd applied to the blood in their lungs, as to bear it's action for a great length of time. But this conjecture, on experiment, was found to be erroneous.

From the experiments upon them, it appears that water lizards, and moft probably the other amphibious animals, die in nitrous oxyd in a much fhorter time than in hydrogen, or pure water; confequently, their death in it cannot depend on the fimple privation of atmofpheric air.

Fifhes.

It was expected that fifhes, like amphibious animals, would have been very quickly deftroyed by the action of nitrous oxyd; but although water faturated with nitrous oxyd had no pofitive effects upon them, they ought, according to Davy, to die in it much fooner than in water deprived of air by ebullition. From their living in it rather longer, it may be concluded, that they are de-

ſtroyed not by privation of atmoſpheric air, but from ſome poſitive change effected in their blood by the gas.

He had long ago obſerved, that the gills of fiſhes became rather of a lighter red during their death in the atmoſphere, and conjectured that the diſeaſe of which they died was probably hyperoxygenation of the blood connected with highly increaſed animal heat. For not only is oxygen preſented to their blood in much larger quantities in atmoſpheric air than in it's aqueous ſolution, but likewiſe in a ſtate in which it contains, to uſe common language, much more *latent heat*. Without, however, laying any ſtreſs on this ſuppoſition, he had the curioſity to try whether thornbacks would live longeſt in atmoſpheric air or nitrous oxyd. In one experiment they appeared to die in them nearly in the ſame time. In another, the fiſh in nitrous oxyd lived nearly half as long again as that in atmoſpheric air. The winged inſects furniſhed with breathing holes became motionleſs in nitrous oxyd very ſpeedily: being, however, poſſeſſed of a certain voluntary power over reſpiration, they ſometimes recover, after having been expoſed to it for ſome minutes, under the action of atmoſpheric air. A butterfly died in nitrous oxyd in ſix minutes; in hydrogen, in five minutes. A large fly became motionleſs in nitrous oxyd in half a minute; in hydrogen, in a quarter of a minute; in hydro-carbonat it dropped immediately ſenſeleſs. Flies live much longer under water, alcohol, or oil, than in nonreſpirable gaſes, or gaſes incapable of ſupporting life. A certain quantity of air always continues attached in the fluid to the fine hairs ſurrounding their breathing holes, ſufficient to ſupport life for a ſhort time. Inſects.

Snails and earth worms live in nitrous oxyd a long while; they die in it, however, much ſooner than in water or hydrogen, probably from the ſame cauſes as amphibious animals. Snails and earth worms.

Having diſcovered that the nitrous oxyd was reſpirable, the next thing was to inveſtigate the changes effected in it by the venous blood; and finding that the reſidual gas of nitrous oxyd, after it had been breathed for ſome time in ſilk bags, was chiefly nitrogen, the conjecture at firſt was, that the nitrous oxyd was decompoſed in reſpiration in the ſame manner as atmoſpheric air, and it's oxygen only combined with the venous blood: but experiments proved the contrary; for it was found,

It's effects on venous blood.

1ſt. That when nitrous oxyd is agitated in fluid venous blood, a certain portion of the gas is abſorbed, whilſt the colour of the blood changes from dark red to red purple.

2d. That during the abſorption of nitrous oxyd by the venous blood, minute portions of nitrogen and carbonic acid are produced, either by evolution from the blood, or from a decompoſition of part of the nitrous oxyd.

3d. That venous blood impregnated with nitrous oxyd is capable of oxygenation; and, *vice verſa*, that oxygenated blood may be combined with nitrous oxyd.

Changes in the nitrous oxyd by reſpiration.

To aſcertain accurately the changes effected in nitrous oxyd by reſpiration, a large mercurial air holder of the capacity of 200 cubic inches was uſed. Whenever the pure nitrous oxyd was breathed after a complete voluntary exhauſtion of the lungs, the pleaſurable delirium was rapidly produced; and being obliged to ſtoop on the cylinder, the determination of blood to the head from the increaſed arterial action in leſs than a minute became ſo great, as often to deprive the experimentaliſt of voluntary power over the muſcles of the mouth. Hence he could never rely on the accuracy of any experiment in which the gas had been reſpired for more than three fourths of a minute. He was able to reſpire the gas with great accuracy for more than half a minute; and in all his experiments on the reſpiration of this nitrous oxyd, a very conſiderable diminution of gas always took place, and the

diminution was in general apparently greater to the eye during the firſt four or five inſpirations.

The reſidual gas of an experiment was always examined as follows: After being transferred through mercury into a graduated cylinder, a ſmall quantity of concentrated ſolution of cauſtic potaſh was intoduced into it, where it remained in contact ſome hours: the diminution was then noted, and the quantity of gas abſorbed by the potaſh judged to be carbonic acid. To the remainder twice it's bulk of pure water was admitted; and, after agitation and reſt for four or five hours the abſorption was noticed, and the gas abſorbed conſidered as nitrous oxyd. The reſidual unabſorbable gas was mingled over water with twice it's bulk of nitrous gas; and by theſe means it's compoſition, whether it conſiſted wholly of nitrogen, or of nitrogen mingled with ſmall quantities of oxygen, aſcertained.

The reſidual gas how examined.

From a number of experiments, the following are ſelected as the moſt accurate on the reſpiration of nitrous oxyd:

1. At temperature 54°, 102 inches of nitrous oxyd were breathed, which contained nearly $\frac{1}{50}$th common air, for about half a minute, ſeven inſpirations and ſeven expirations being made. After every expiration an evident diminution of gas was perceived; and on the laſt full expiration it filled a ſpace equal to 62 cubic inches.

Theſe 62, being analyſed, were found to conſiſt of

Carbonic acid	3.2
Nitrous oxyd	29.0
Oxygen	4.1
Nitrogen	25.7
	62.0

Hence, accounting for the two cubic inches of common

air previously mingled with the nitrous oxyd, 71 cubic inches had disappeared.

2. At temperature 47°, 182 were breathed, with 2½ of atmospheric air of the air holder, for 40 seconds—in all eight respirations. The gas after the last expiration equalled 128 cubic inches, which, on analysis, consisted of

Carbonic acid	5.25
Nitrous oxyd	88.75
Oxygen	5.00
Nitrogen	29.00

Consequently 93.25 cubic inches had disappeared in this experiment. Hence nitrous oxyd is rapidly absorbed by the venous blood through the moist coats of the pulmonary veins. But as, after a complete voluntary exhaustion of the lungs, much residual air must remain in the bronchial vessels and fauces, as appears from their incapability of completely collapsing, it is evident that the gas expired after every inspiration of nitrous oxyd must be mingled with different quantities of the residual gas of the lungs; and after a complete expiration, much of the unabsorbed nitrous oxyd must remain as residual gas in the lungs. Now, when a complete expiration is made after the breathing of atmospheric air, it is evident that the residual gas of the lungs consists of nitrogen mingled with small portions of oxygen and carbonic acid, because these products are formed during the respiration of common air, and they are the only products found after the respiration of nitrous oxyd.

To ascertain whether these products were partly produced during the process of respiration, or whether they were wholly the residual gases of the lungs, was found extremely difficult. The first, however, is the most probable.

For this purpose the author first thought of breathing nitrous oxyd immediately after his lungs had been filled

with oxygen, and to compare the products remaining after the full expiration with thofe produced after a full expiration of pure oxygen; but this idea was relinquifhed. He attempted to infpire nitrous oxyd, after having made two infpirations, and a complete expiration of hydrogen; but the effects of the hydrogen were fo debilitating, and the confequent ftimulation by the nitrous oxyd fo great, as to deprive him of fenfe.

Though experiments on fucceffive infpirations of pure nitrous oxyd might go fo far as to determine whether or no any nitrogen, carbonic acid, and oxygen were products of refpiration; yet he diftinctly faw that it was impoffible in this way to afcertain their quantities, fuppofing them produced, unlefs he could firft determine the capacity of his lungs, and the different proportions of the gafes remaining in the bronchial veffels after a complete expiration, when atmofpheric air had been refpired. In fome experiments (made on the refpiration of hydrogen, to determine whether carbonic acid was *produced* by the combination of carbon loofely combined in the venous blood with the oxygen refpired, or whether it was fimply *given out* as excrementitious by this blood) he found, without being able to refolve the problem, that in the refpiration of pure hydrogen, little or no alteration of volume took place; and that the refidual gas was mingled with fome nitrogen, and a little oxygen and carbonic acid.

From the comparifon of thefe facts with thofe on the abforption of nitrous oxyd by venous blood, and on the effects produced upon animals by the refpiration of nitrous oxyd, there was every reafon to fuppofe that hydrogen was not abforbed or altered, when refpired, but only mingled with the refidual gafes of the lungs.

Hence, by making a full expiration of atmofpheric air, and afterwards taking fix or feven refpirations of hydrogen in the mercurial air-holder, and then making

a complete expiration, he thought that the refidual gas and the hydrogen would be fo mingled, as that nearly the fame proportions fhould remain in the bronchial veffels as in the air-holder. By afcertaining thefe proportions, and calculating from them, he hoped to be able to afcertain with tolerable exactnefs the capacity of his fauces and bronchia, as well as the compofition of the gas remaining in them, after a complete expiration of common air.

To afcertain the capacity of the fauces and bronchia, and the compofition of the gas remaining in them.

Hydrogen.—The hydrogen employed for this purpofe was procured from the decompofition of water by means of clean iron filings and diluted fulphuric and muriatic acids. It was breathed in the fame manner as nitrous oxyd, in the large mercurial air-holder. The difficulty of making the experiments was great, from the difficulty of breathing hydrogen for half a minute fo as to make a complete expiration of it, after a complete voluntary exhauftion of the lungs. The purity of the hydrogen was afcertained immediately before the experiment by the teft of nitrous gas, and by detonation with oxygen in atmofpheric air: generally 12 meafures of atmofpheric air were fired with four of the hydrogen; and if the diminution was to ten or a little more, the gas was judged pure. After the experiment, when the complete expiration had been made, and the common temperature reftored, the volume of the gas was noticed, and then a fmall quantity of it thrown into the mercurial apparatus, by means of the conducting tube, to be examined. The carbonic acid was feparated by folution of potafh or ftrontian; the quantity of oxygen afcertained by nitrous gas of known compofition; the fuperabundant nitrous gas was abforbed by a folution of muriat of iron; and the proportions of hydrogen and nitrogen in the remaining gas difcovered by inflammation with atmofpheric air or oxygen in the detonating tube by the electric fpark.

The two following experiments on quantities of hydrogen, equal to thoſe of the nitrous oxyd, reſpired in the foregoing experiments, are the moſt accurate of five.

Exp. 1. He reſpired at 59°, 102 cubic inches of hydrogen, apparently pure, for rather leſs than half a minute, making ſeven quick reſpirations. After the complete expiration, when the common temperature was reſtored, the gas occupied a ſpace equal to 103 cubic inches nearly. Theſe analyſed were found to conſiſt of

Carbonic acid	4.0
Oxygen	3.7
Nitrogen	17.3
Hydrogen	78.0
	103.0

Now, as in this experiment the gas was increaſed in bulk only a cubic inch; ſuppoſing that after the complete expiration the gas in the lungs, bronchia, and fauces, was of nearly ſimilar compoſition with that in the air-holder, and that no hydrogen had been abſorbed by the blood, it would follow that 24 cubic inches of hydrogen remained in the internal organs of reſpiration, and conſequently, by the rule of proportion, about 7.8 of the mixed reſidual gas of the common air. And then the whole quantity of reſidual gas of the lungs, ſuppoſing the temperature 59°, would have been 31.8 cubic inches; but as it's temperature was nearly that of the internal parts of the body, 98°, it muſt have filled a greater ſpace; calculating from the experiments of Guyton and Vernois (An. de Ch. t. i. p. 979) about 37.5 cubic inches.

From the increaſe of volume, it would appear that a minute quantity of gas had been generated during the reſpiration; and this was moſt probably carbonic acid: for

there is no reaſon to ſuppoſe the production of nitrogen. There is alſo reaſon to ſuppoſe that a little of the reſidual oxygen muſt have been abſorbed. Making allowances for theſe circumſtances, it would follow that the 37.5 cubic inches of gas remaining in the lungs of the operator, after a complete expiration of atmoſpheric air, animal heat 98°, equal to 31.3 cubic inches at 59°, were compoſed of

Nitrogen	24.9
Carbonic acid	4.9
Oxygen	5.0
	31.8

Exp. 2. He reſpired for near a minute and a half in the mercurial air-holder at 61°, 182 cubic inches of hydrogen, making ſix long inſpirations. After the laſt expiration, the gas filled a ſpace nearly equal to 184 cubic inches, and analyſed was found to conſiſt of

Carbonic acid	4.8
Oxygen	4.6
Nitrogen	21.0
Hydrogen	153.6
	184.0

Now in this experiment, reaſoning as before, 28.4 cubic inches of hydrogen muſt have remained in the lungs, and likewiſe 5.5 of the atmoſpheric reſidual gas. Conſequently, the whole reſidual gas was nearly equal to 34 cubic inches at 61°, which at 98° would become about 40.4 cubic inches. And it would appear alſo, that the quantity of gas remaining in the lungs, after a complete voluntary reſpiration, equalled at 98°, about 40 cubic inches, and at 61°, 34 nearly; that after common air had been breathed, the 34 cubic inches conſiſted of

Carbonic acid	4.1
Oxygen	5.5
Nitrogen	24.4
	34.0

It would have been poffible, according to the operator, to prove the truth of the poftulate on which the experiments were founded, by refpiring common air or oxygen after the complete expiration of the hydrogen, for the fame time as the hydrogen was refpired, and in equal quantities. For, if portions of hydrogen were found in the air-holder equal to thofe of the refidual gases in the two experiments, it would prove that a *uniform* mixture of refidual gas, with the gas infpired, was produced by the refpiration. This mixture, however, appeared fo evident from analogous facts as to make the proofs unneceffary.

Indeed, as moft gafes, though of different fpecific gravities, when brought into contact with each other, affume fome fort of union, it is more than probable that gas infpired into the lungs, from being placed in contact with the refidual gas on fuch an extenfive furface, muft inftantly mingle with it. Hence, poffibly one deep infpiration and complete expiration of the whole of a quantity of hydrogen of the lungs after complete voluntary exhauftion, will be fufficient to determine the capacity and the nature of the refidual air.

That two infpirations are fufficient, appears probable from the following

Exp. 3. After a complete voluntary expiration of common air, he made two deep infpirations of 141 cubic inches of hydrogen. After the complete expiration, they filled a fpace equal to rather more than 142 cubic inches, and analyfed were found to confift of

Carbonic acid	3.1
Oxygen	4.5
Nitrogen	18.8
Hydrogen	115.6
	142.0

Calculating from this experiment on the exhaufted capacity of the lungs, fuppofing uniform mixture, they would contain, after expiration of common air, about 30.7 cubic inches at 58°, equal to 36 at 98°, compofed of about

Nitrogen	20.9
Oxygen	5.8
Carbonic acid	4.0
	30.7

It might be fuppofed, a *priori*, that in this experiment much lefs of the refidual oxygen of the lungs muft have been abforbed, than in experiments 1 and 2; yet there is no very marked difference in the portions evolved. That a tolerably accurate mixture took place, appears from the quantity of nitrogen. The fmaller quantity of carbonic acid is an evidence in favour of it's evolution from the venous blood.

It is reafonable to fuppofe that the preffure upon the refidual gas of the exhaufted lungs muft be nearly equal to that of the atmofphere; but as aqueous vapour is perpetually given out by the exhalents, and perhaps evolved from the moift coats of the pulmonary veffels, it is likely that the refidual gas is not only fully faturated with moifture at 98°, but likewife impregnated with uncombined vapour, and hence it's volume enlarged beyond the

increment of expanſion of temperature. Conſidering all theſe circumſtances, and calculating from the mean of the three experiments on the compoſition of the reſidual gas, Davy concludes—

1ſt. That the exhauſted capacity of his lungs was equal to about 41 cubic inches.

2d. That the gas contained in the bronchial veſſels and fauces, after a complete expiration of atmoſpheric air, was equal to about 32 cubic inches—it's temperature being reduced to 55°.

3d. That theſe 32 cubic inches were compoſed of about

Nitrogen, ...	23.0
Carbonic acid, ...	4.1
Oxygen, ...	4.9
	32.0

In many experiments made in the mercurial air-holder, on the capacity of the lungs under different circumſtances, he found that he threw out of his lungs, by a full forced expiration, at temperature from 58° to 62°,

	Cubic Inches.
After a full voluntary inſpiration, from	189 to 191
After a natural inſpiration, from	78 to 79
After a natural expiration, from	67 to 68

So that, making the corrections for temperature, it would appear that his lungs in a ſtate of voluntary inſpiration contained about 254 cubic inches; in a ſtate of natural inſpiration about 135; in a ſtate of natural expiration about 118; and in a ſtate of forced expiration 41. But as the exhauſted capacity, as well as impleted capacity, of the internal organs of reſpiration muſt be different in different individuals, according as the forms and ſize of their thorax, fauces, and bronchia are different, it would

be almoft ufelefs to endeavour to afcertain a ftanding capacity. It is, however, probable, that a ratio exifts between the quantities of air infpired in the natural and forced infpiration, thofe expired in the natural and forced expiration, and the whole capacity of the lungs. If this ratio were afcertained, a fingle experiment on the natural infpiration and expiration of common air would enable us to afcertain the quantity of refidual gas in the lungs of any individual after a complete forced expiration. The operator is of opinion that the capacity of his own lungs is below the medium—his cheft being narrow, meafuring in circumference only twenty-nine inches, and his neck rather long and flender.

Comments on the experiments on the refpiration of nitrous oxyd.

Having thus afcertained the capacity of his lungs, and the compofition of the refidual gas of expiration, it remained to reafon on the experiments on the refpiration of nitrous oxyd.

In experiment I, nearly 100 cubic inches of nitrous oxyd (making the corrections on account of the common air) were refpired for half a minute. In this time they were reduced to 62 cubic inches; which confifted of 3.2 carbonic acid, 29 nitrous oxyd, 4.1 oxygen, and 25.7 nitrogen.

But, as appears from the laft fection, there exifted in the lungs, before the infpiration of the nitrous oxyd, about 32 cubic inches of gas, confifting of 23 nitrogen, 4.1 carbonic acid, and 4.9 oxygen—temperature being reduced to 59°. This gas muft have been perfectly mingled with the nitrous oxyd during the experiment; and, confequently, the refidual gas in the lungs, after the experiment, was of the fame compofition as that in the air-holder.

Suppofing it, as before, to be about 32 cubic inches, from the rule of proportion they will be compofed of

Nitrous oxyd, ...	14.7
Nitrogen, ...	13.3
Carbonic acid, ...	1.9
Oxygen, ...	2.1
	32.0

And the whole quantity of gas in the lungs and the air-holder, fuppofing the temperature 59°, will equal 94 cubic inches; which are compofed of

Nitrous oxyd, ...	43.7
Nitrogen, ...	39.0
Carbonic acid, ...	5.2
Oxygen, ...	6.1
	94.0

But, before the experiment, the gas in the lungs and air-holder equalled 134 cubic inches; and thefe, reckoning for the common air, were compofed of

Nitrous oxyd	100.0
Nitrogen, ...	24.3
Carbonic acid, ...	4.1
Oxygen, ...	5.6
	134.0

Hence it appears, that 56.3 cubic inches of nitrous oxyd were abforbed in this experiment, and 13.7 of nitrogen produced, either by evolution from the blood, or decompofition of the nitrous oxyd. The quantities of carbonic acid and oxygen approach fo near to thofe exifting after the refpiration of hydrogen, that there is every reafon to believe that no portion of them was produced in confequence of the abforption or decompofition of the nitrous oxyd.

In Experiment II, calculating in the ſame manner, before the firſt inſpiration a quantity of gas, equal to 216.5 cubic inches at 47°, exiſted in the lungs and air-holder; and theſe 216.5 were compoſed of

Nitrous oxyd, ...	182.0
Nitrogen, ...	24.9
Carbonic acid, ...	4.1
Oxygen, ...	5.5
	216.5

After the complete expiration, 160 cubic inches remained in the lungs and air-holder; which were compoſed of

Nitrous oxyd, ...	110.6
Nitrogen, ...	36.3
Carbonic acid, ...	6.8
Oxygen, ...	6.3
	160.0

Hence it appears that 71.4 cubic inches of nitrous oxyd were abſorbed in this experiment, and about 12 of nitrogen produced. The quantity of carbonic acid and oxygen is rather greater than that which exiſted in the experiments on hydrogen.

Nitrogen produced during reſpiration of nitrous oxyd.

From theſe eſtimations he learned that a ſmall quantity of nitrogen was produced during the abſorption of nitrous oxyd in reſpiration. It remained to determine whether this nitrogen owed it's production to evolution from the blood, or to the decompoſition of a portion of the nitrous oxyd.

Analogical evidences were not in favour of the hypotheſis of decompoſition. It was difficult to ſuppoſe that a body requiring the temperature of ignition for it's decompoſition by the moſt inflammable bodies, ſhould be partially abſorbed and partially decompounded at 98° by a fluid apparently poſſeſſed of uniform attractions. It was more eaſy to believe that, from the immenſe quantity

of nitrogen taken into the blood in nitrous oxyd, the fyftem foon became overcharged with this principle; which not being wholly expended in new combinations during living action, was liberated in the aeriform ftate by the exhalants, or through the moift coats of the veins. If the laft rationale were true, it would follow that the quantity of nitrogen produced in refpiration ought to be increafed in proportion as a greater quantity of nitrous oxyd entered into combination with the blood.

To afcertain whether this was the cafe, he made, after full voluntary exhauftion of his lungs, one full voluntary infpiration and expiration of 108 cubic inches of nitrous oxyd. After this it filled a fpace nearly equal to 99 cubic inches; the quantities of carbonic acid and oxygen in thefe were not determined; but by the teft of abforption by water, they appeared to contain only 18 nitrogen, which is very little more than fhould have been given from the refidual gas of the lungs. In a fecond experiment he made two infpirations of 108 cubic inches of nitrous oxyd nearly pure: the diminution was to 95. On analyfing thefe 95, he found, to his great furprife, they contained only 17 nitrogen. Hence he fufpected fome fource of errour in the procefs.

He now introduced into a ftrong new filk bag, the fides being in perfect contact, eight quarts of nitrous oxyd: it was mingled, from the mode of introduction, with a little common air, but not fufficient to difturb the refults. He then adapted a cork cemented to a long curved tube to his right noftril; the tube communicated with the water apparatus; and the left noftril being accurately clofed, and the mouth-piece of the filk bag lightly adapted to the lips, he made a full expiration of the common air of his lungs, infpired nitrous oxyd from the bag, and, by carefully clofing the mouth-piece with his tongue, expired it through the curved tube into the water apparatus. In

this way he made nine refpirations of nitrous oxyd. The expired gas of the firft refpiration was not preferved; but part of the gas of the 2d, 3d, 5th, 7th, and 9th, were caught in feparate graduated cylinders. The 2d, analyfed by abforption, confifted of about 29 abforbable gas, which muft have been chiefly nitrous oxyd; and 17 unabforbable gas, which muft have been chiefly nitrogen; and the 3d of 22 abforbable gas and eight unabforbable. The fifth was compofed of 27 to 6; the 7th of 23 to 7; and the 9th of 26 to 11.

Though the refults of thefe experiments were not fo conclufive as could be wifhed; yet, comparing them with thofe of the experiments on the changes effected in nitrous oxyd by refpiration, it feemed reafonable to conclude that the production of nitrogen was increafed in proportion as the blood became more fully impregnated with nitrous oxyd.

From this conclufion, compared with the phenomena noticed on the abforption of nitrous oxyd by venous blood, and on the changes effected on the organifation of warm-blooded animals, by the refpiration of nitrous oxyd, he is induced to believe that the production of nitrogen, during the refpiration of nitrous oxyd, is not owing to the decompofition of part of the nitrous oxyd in the aëriform ftate *immediately* by the attraction of the red particles of venous blood for it's oxygen; but that it is rather owing to a new arrangement produced in the principles of the impregnated blood during circulation; from which, becoming fuperfaturated with nitrogen, it gives it out through the moift coats of the veffels.

Production of nitrogen from the new arrangement in the principles of the impregnated blood.

For if any portion of nitrous oxyd were decompofed immediately by the red particles of the blood, the quantity of nitrogen produced ought to be greater during the firft infpirations, before thefe particles became fully combined with condenfed oxygen. If, on the contrary, the

whole of the nitrogen and oxygen of the nitrous oxyd were both combined with the blood and carried through the pulmonary veins and left chamber of the heart to the arteries, then, ſuppoſing the oxygen chiefly expended in living action, whilſt the nitrogen was only partially conſumed in new combinations, it would follow that the venous blood of animals made to breathe nitrous oxyd, hyperſaturated with nitrogen, muſt be different from common venous blood; and there is reaſon to believe this from the phenomena, on the changes effected in the organiſation of warm-blooded animals by the reſpiration of nitrous oxyd.

Of the other products, carbonic acid and water.

Beſides nitrogen, carbonic acid and water have been noticed to be the products of the reſpiration of nitrous oxyd.

As nearly equal quantities of carbonic acid are produced, whether hydrogen or nitrous oxyd is reſpired, provided the proceſs is carried on for the ſame time, there is every reaſon to believe that no part of the carbonic acid produced is generated from the immediate decompoſition of nitrous oxyd by carbon exiſting in the blood: hence it muſt be either evolved from the venous blood, or formed by the ſlow combination of the oxygen of the reſidual air of reſpiration with the charcoal of the blood.

But if it was produced from the decompoſition of reſidual atmoſpheric air, it would follow that it's volume muſt be much leſs than that of the oxygen of the reſidual air which had diſappeared; for ſome of this oxygen muſt have been *abſorbed* by the blood, and during the converſion of oxygen into carbonic acid by charcoal a ſlight diminution of volume is produced.

In the experiments when nitrous oxyd and hydrogen were reſpired for half a minute, the medium quantity of carbonic acid produced was 5.6 cubic inches.

Suppoſe the quantity of carbonic acid produced is in

the ratio of the oxygen diminifhed, and there is every reafon to believe that, in the expiration of atmofpheric air, the expired air and the refidual air are nearly of the fame compofition. Hence no more carbonic acid can remain in the lungs, or be produced from the refidual gas, after the complete expiration of common air, than that which can be generated from a volume of atmofpheric air equal to the refidual gas of the lungs. This refidual gas, after complete expiration, equals at 55°, 32 cubic inches, and 32 cubic inches of common air contain 8.6 cubic inches of oxygen. But in the experiments on the refpiration of hydrogen, not only 5.6 cubic inches of carbonic acid were produced, but more than four of refidual oxygen remained unabforbed.

The carbonic acid evolved through the coats of the veffels.

Hence it appears impoffible that all the carbonic acid could have been produced by the combination of charcoal in the venous blood with refidual atmofpheric oxygen; there is therefore every reafon to believe, that it is wholly or partially liberated from the venous blood through the moift coats of the veffels. The water carried out of the lungs in folution, by the expired gas of nitrous oxyd, could neither have been wholly nor partially formed by the decompofition of nitrous oxyd. The coats of the veffels in the lungs, and indeed in the whole internal furface of the body, are always covered with moifture; and the folution of part of this moifture by the infpired heated gas, and it's depofition by the expired gas, are, according to Davy, fufficient caufes for the appearance of the phenomenon. There are no reafons for fuppofing that any of the refidual atmofpheric oxygen is immediately combined with fixed or nafcent hydrogen, or hydrocarbonat, in the venous blood, at 98°, by flow combuftion, and confequently none for fuppofing that water is immediately formed in refpiration. The evolution of water from the veffels in the lungs is almoft certain from nu-

The water evolved from the

merous analogies. He found that nitrous oxyd can be respired without danger by man for a much longer time than that required for the death of the smaller quadrupeds in it. He has breathed it two or three times in a considerable state of purity for four minutes and a quarter, and four minutes and a half, and some diseased individuals for five minutes. Three quarts, *i. e.* about one hundred and seventy-four cubic inches, are consumed so as to be unfit for respiration by a healthy individual with lungs of moderate capacity in about one minute and a quarter; six quarts, or 348 cubic inches, last generally for two minutes and half or two minutes and three quarters; eight quarts, or 464 cubic inches, for more than three minutes and half; and 12 quarts, or 696 cubic inches, for nearly five. He is inclined to believe that nitrous oxyd is absorbed more rapidly after heavy meals, or during stimulation from wine or spirits, than at other times; and as it's absorption appears to depend on a simple solution in the venous blood, probably diminution of temperature will increase it's capability of being absorbed. The range of the consumption of different individuals does not extend to more than a pint, or 30 cubic inches, at the maximum dose; hence the medium of consumption is not far from two cubic inches, or about a grain every second, or 120 cubic inches, or 60 grains, in a minute. When nitrous oxyd is breathed in tight silk bags, towards the end of the experiment, as the internal surface becomes moist, a certain quantity of common air penetrates through; but it is too small to destroy any of the effects of the nitrous oxyd.

vessels in the lungs.

Having thus ascertained the absorption of nitrous oxyd in respiration, and the evolution of nitrogen and carbonic acid from the lungs, during it's absorption, he was anxious to compare the changes effected in this gas, with those produced in nitrous oxyd and oxygen; considering

On the respiration of atmospheric air.

atmofpheric air as a compound, in which principles identical with thofe in nitrous oxyd exifted, though in different quantities and loofer combination.

The compofition of the atmofpheric air before infpiration, and after expiration, was afcertained in the following manner: 40 meafures of it were agitated over mercury in folution of cauftic potafh, and here it remained two or three hours in contact. The diminution was noted, and the gas abforbed judged to be carbonic acid. Twenty meafures of the gas, freed from carbonic acid, were mingled with 30 of nitrous gas, in a tube of five inches diameter; they were *not agitated*, but fuffered to reft an hour or an hour and half, when the volume occupied by them was noticed; and 50—m the volume occupied, divided by three, confidered as the oxygen x, and 20—x confidered as the nitrogen. When they are *agitated* a greater proportion of nitrous gas is abforbed and condenfed in the nitric acid by the water; and to find the oxygen $x = \frac{50-m}{3.4}$ or $\frac{50-m}{3.5}$

Exp. 1. To afcertain the changes effected in atmofpheric air by fingle infpirations, he made after a complete voluntary exhauftion of his lungs, at temperature 61°, one infpiration and expiration of 141 cubic inches of this air. After expiration they filled a fpace equal to 139 cubic inches. Thefe analyfed were found to confift of

Nitrogen	101
Oxygen	32
Carbonic acid ..	6

The 141 cubic inches before refpiration were compofed of 103 nitrogen, 1 carbonic acid, and 37 oxygen. The time taken to perform the infpiration and full expiration was a quarter of a minute. He repeated this experiment feven or eight times, and the quantity of oxygen abforbed was generally from five to fix cubic inches;

the carbonic acid formed from five to 5.5, and the quantity of nitrogen apparently diminiſhed from one to three cubic inches.

Exp. 2. After a voluntary expiration of common air, he made one inſpiration and full expiration of 100 cubic inches of atmoſpheric air. It was diminiſhed nearly to 98¾ or 99 cubic inches, and, analyſed, was found to conſiſt of

Nitrogen	71.7
Oxygen	22.5
Carbonic acid	4.5

This was repeated four or five times with little difference of reſult, and there always ſeemed to be a ſmall diminution of nitrogen. He found he took into his lungs at every natural inſpiration 13 cubic inches of air, and threw out at every expiration rather leſs, or about 12¾ cubic inches.

The mean compoſition of the 13 cubic inches of air inſpired was

Nitrogen	9.5	cubic inches
Oxygen	3.4	
Carbonic acid ...	0.1	

That of the 12.7 of air expired

Nitrogen	9.3	cubic inches
Oxygen	2.2	
Carbonic acid	1.2	

Theſe reſults he gained from more than 20 experiments, which ſhow their accuracy. He made about 26 or 27 natural inſpirations a minute. So that, calculating from the above eſtimations, it follows, that 31.6 cubic inches of oxygen were conſumed, and 5.2 cubic inches of nitrogen loſt in reſpiration every minute, whilſt 26.6 cubic inches of carbonic acid were produced.

To collect the products of a great number of natural expirations, ſo as to aſcertain whether their compoſition

correfponded with the above accounts, he faftened his lips tight on the mouthpiece of the exhaufted airholder, and, fuffering his noftrils to remain open, infpired naturally through them, throwing the expired air through his mouth into the airholder.

In many experiments, he found that in about half a minute he made in this way 14 or 15 expirations. The mean quantity of air collected was 171 cubic inches, and confifted of

Nitrogen	128	cubic inches
Oxygen..........	29	
Carbonic acid	14	

On comparing thefe refults with the former ones, the mean quantities of air refpired in equal times are rather lefs; but the proportions of carbonic acid, nitrogen, and oxygen, in the refpired air, nearly identical.

To afcertain the changes effected in a given quantity of atmofpheric air by continued refpirations, he breathed, after a complete expiration, at temperature 63°, 161 cubic inches of air for near a minute, making 19 deep infpirations. After the complete expiration, the gas filled a fpace nearly equal to 152 cubic inches, fo that nine cubic inches of gas had difappeared.

The 152 cubic inches, analyfed, were found to confift of

Nitrogen	111.6	cubic inches
Oxygen, ...	23.	
Carbonic acid	17.4	

The 161 cubic inches before infpiration were compofed of

Nitrogen	117.0	cubic inches
Oxygen	42.4	
Carbonic acid	1.6	

But the refidual gas in the lungs, before the experiment, was of different compofition from that remaining in the lungs after the experiment. It appears, therefore, after

making proper corrections, that about 5.1 of nitrogen were absorbed in respiration, 23.9 of oxygen consumed, and 12 of carbonic acid produced. This c periment was repeated three times with similar results, and the residual gas of similar composition. So that, supposing the existence of no source of error in the experiments, from which the quantity and composition of the residual gas of the lungs were estimated, the absorption of nitrogen as Priestley had suspected, by venous blood, appears demonstrated. To compare the changes effected in atmospheric air by respiration of the smaller quadrupeds with the above, he introduced into a 20-cubic-inch jar, filled with mercury in the mercurial trough, 15 cubic inches of atmospheric air, deprived of it's carbonic acid by long exposure to solution of potash. Temperature being 64°, a healthy small mouse was quickly passed under the mercury into the jar. He continued nearly 49 minutes without apparently suffering, at 20 minutes he lay on his side, and in 55 minutes was apparently dying, but exposed to the warmth of a fire recovered. The gas in the jar filled a space nearly equal to 14 cubic inches; so that a diminution of a cubic inch had taken place. These 14 cubic inches, analysed, consisted of

Carbonic acid	2.0 cubic inches
Oxygen	1.4
Nitrogen	10.6

The 15 cubic inches before the experiment consisted of

Oxygen	4 cubic inches
Nitrogen	11

Hence 2.6 cubic inches of oxygen had been consumed, two cubic inches of carbonic acid produced, and about 0.4 of nitrogen lost. The relation, therefore, between the quantities of oxygen consumed, and carbonic acid produced, are nearly the same as those in the former experiments; but the quantity of nitrogen lost is much smaller.

Refpiration of oxygen.

The gafes before and after refpiration were analyfed in thefe experiments as in the laft, except that three of nitrous gas were always employed to one of oxygen.

Exp. 1. At temperature 53°, after a full forced expiration, he refpired in the mercurial airholder, for half a minute, 102 cubic inches of oxygen, making feven long and deep infpirations. After the complete expiration, the gafes filled a fpace equal to 93 cubic inches: thefe 93, analyfed, confifted of

Carbonic acid	5.9 cubic inches
Nitrogen	33.8
Oxygen	53.3

The 102 cubic inches before the experiment were compofed of

Oxygen	78 cubic inches
Nitrogen	24

The refidual gas in the lungs, before the experiment, was 32 cubic inches, and compofed of 23 nitrogen, 4.1 carbonic acid, and 4.9 oxygen. The refidual gas, after expiration, of 18.2 oxygen, two carbonic acid, and 11.8 nitrogen.

Hence the whole of the gas in the lungs and airholder before infpiration was 134 cubic inches, compofed of

Oxygen	82.9 cubic inches
Nitrogen	47.0
Carbonic acid ...	4.1

and after refpiration, 125 cubic inches, confifting of

Oxygen	71.5 cubic inches
Nitrogen	45.6
Carbonic acid ...	7.9

fo that, comparing the quantities, it appears that 11.4 of oxygen, and 1.4 of nitrogen, were confumed in this experiment, and 3.8 of carbonic acid produced. He was furprifed at the fmall quantity of oxygen confumed, being lefs than that during the refpiration of atmofpheric air

for half a minute: the portion of carbonic acid evolved was ſmaller.

Exp. 2. He reſpired at the ſame temperature, after a full expiration, 162 cubic inches of gas, compoſed of 133 ozygen, and 29 nitrogen, for two minutes. After the experiment they were equal to 123 cubic inches. On analyſis it appeared, that 57 cubic inches of oxygen, and two of nitrogen, had been abſorbed, whilſt 21 cubic inches of carbonic acid had been formed. It appears, therefore, from the eſtimations in the laſt ſection, that 63 cubic inches of oxygen are conſumed, and about 52 cubic inches of carbonic acid produced, every two minutes, during the natural reſpiration of common air. So that ſix cubic inches leſs of oxygen are abſorbed, and 30 cubic inches leſs of carbonic acid produced, every minute, when oxygen nearly pure is reſpired than when atmoſpheric air is reſpired.

Comparative conſumption of atmoſpheric air and oxygen.

To aſcertain the comparative conſumption of atmoſpheric air and oxygen, by the ſmaller quadrupeds, he procured two healthy mice.

Exp. 3. One was introduced into a jar, containing $10\frac{1}{2}$ cubic inches of oxygen, and three cubic inches of nitrogen, and made to reſt on a bit of cheeſe. The other was introduced into a jar containing $15\frac{1}{2}$ cubic inches of atmoſpheric air. In the firſt it ſuffered in half an hour, and was dying in one hour. The jars were often agitated, that the gaſes might be well mingled. The mouſe in the atmoſpheric air was feeble in 40 minutes, and in 50 unable to ſtand.

The gas in the oxygen jar filled a ſpace equal to 12.7 cubic inches, and, analyſed, conſiſted of 1.7 carbonic acid, 2.6 nitrogen, and 8.4 of oxygen. So that 2.1 cubic inches of oxygen had been conſumed, and 0.4 of nitrogen, and 1.7 of carbonic acid produced.

The gas in the atmoſpheric jar was diminiſhed nearly

to 14.4, and confifted of 2.1 carbonic acid, 1.4 oxygen, and 10.9 nitrogen. So that 2.7 of oxygen, and five of nitrogen had been confumed, and 2.1 of carbonic acid produced.

It appears therefore that the moufe in atmofpheric air confumed nearly one third more oxygen, and produced nearly a quarter more carbonic acid in 55 minutes than the other in an hour and a quarter in oxygen.

On the changes effected in the blood by atmofpheric air and oxygen.

From the experiments of Cigna and Prieftley, the coagulum of the venous blood becomes florid at it's furface when expofed to the atmofphere, though covered and defended from the immediate contact of the air by a very dark ftratum of ferum. Hence ferum is capable of diffolving either the whole compound atmofpheric air, or it's oxygen. Suppofing it diffolves the whole, it follows, that the colouring of the coagulum of blood under ferum depended on the decompofition of the atmofpheric air condenfed in the ferum; it's oxygen combining with the red particles and the nitrogen, either remaining diffolved in the fluid, or being liberated through it into the atmofphere; for the circulating blood confifts of red particles, floating in and diffufed through ferum and coagulable lymph. In natural refpiration, the red particles are rendered of a brighter tinge during the paffage of the blood through the pulmonary veins: and, as before feen, during refpiration, atmofpheric air is decompofed, all the oxygen of it confumed, *apparently* a fmall proportion of the nitrogen loft, and a confiderable quantity of carbonic acid produced.

Moft probably, the whole compound atmofpheric air, paffing through the moift coats of the veffels, is firft diffolved by the ferum of the venous blood, and in it's condenfed ftate decompofed by the affinity of the red particles for it's oxygen, the greater part of the nitrogen being liberated unaltered, but a minute portion of it poffibly re-

2

maining condenfed in the ferum and coagulable lymph, and paffing with them into the left chamber of the heart.

From the experiments on the refpiration of nitrous oxyd and hydrogen, it appears that a certain portion of the carbonic acid produced is evolved from the venous blood; but, as a much greater quantity is generated during the refpiration of common air and oxygen than during that of hydrogen in equal times, it is not impoffible but that fome portion of it may be formed by the combination of charcoal in the red particles with the oxygen diffolved in the ferum.

Suppofing that no part of the water evolved in folution by the expired gas of common air is formed immediately in refpiration, it will follow that a very confiderable quantity of oxygen muft be conftantly *combined* with the red particles, even allowing the confumption of a certain portion of it to form carbonic acid; for the carbonic acid evolved rarely amounts to more than three-fourths of the volume of the oxygen confumed. Perhaps the ferum is capable of diffolving a larger quantity of atmofpheric air than of pure oxygen.

Obfervations on the refpiration of nitrous oxyd.

It therefore appears that nitrous oxyd, when refpired by animals, produces peculiar changes in their blood and in their organs, firft connected with increafed living action, but terminating in death; that it is rapidly abforbed by the circulating venous blood, and of courfe it's condenfed oxygen and nitrogen diftributed in the blood over the whole of the fyftem.

He could breathe nine quarts of nitrous oxyd for three minutes, and twelve for rather more than four, but could never breathe it in any quantity fo large as five. When it's operation was carried to the higheft extent, the pleafurable thrilling about it's height about the middle of the experiment gradually diminifhed, the fenfe of preffure on

the mufcles was loft, impreffions ceafed to be perceived, voluntary power deftroyed, and the mouthpiece generally dropped from his unclofed lips.

He made fome experiments to afcertain the analogy that exifted between the fenfible effects of the different gafes, which are fooner or later fatal to life when refpired, and thofe of nitrous oxyd.

Hydrogen. Pure hydrogen had been often refpired by different philofophers, particularly by Scheele, Fontana, and Rofier. Davy refpired four quarts of it, nearly pure, produced from zinc and muriatic acid, for near a minute; his lungs being previoufly exhaufted, and his noftrils carefully clofed. The firft fix or feven infpirations produced no fenfations whatever; in half a minute his cheft was oppreffed, which gradually increafed until the pain of fuffocation obliged him to leave off. He felt no giddinefs, his pulfe was feebler and quicker, and his cheeks at laft became purple. When the hydrogen was procured from iron and diluted vitriolic acid, he was unable to refpire three-fourths of a minute; giddinefs and debility were produced, the pulfe feeble, and the fuffocation greater than before.

Nitrogen. He breathed three quarts of nitrogen, mingled with a very fmall portion of carbonic acid, for near a minute. It produced no alteration for twenty feconds; then the fenfe of fuffocation gradually came on, and increafed rapidly the laft quarter of the minute, fo as to compel him to defift. The pulfe was feebler and quicker. The head not affected.

Hydro-carbonat. Watt's obfervations on the refpiration of diluted hydrocarbonat by men, and Dr. Beddoes' experiments on animals by pure hydro-carbonat, proved it's effects to be highly deleterious. Davy breathed for near a minute three quarts of it mingled with nearly two quarts of atmofpheric air, which had never been breathed fo little

diluted before. It produced a flight giddinefs and pain in the head, and a momentary lofs of voluntary power. He then refolved to breathe pure hydro-carbonat: for this purpofe, he introduced into a filk bag four quarts of gas, nearly pure, produced from the decompofition of water by charcoal an hour before, and which had a ftrong and difagreeable fmell. After a forced exhauftion of the lungs, and the nofe being accurately clofed, he made three infpirations and expirations. The firft produced a fort of numbnefs and lofs of feeling in the cheft, and about the pectoral mufcles. After the fecond infpiration he loft all power of perceiving external things, and had no diftinct fenfation, except a terrible oppreffion on the cheft. During the third expiration this feeling difappeared, and he feemed finking into annihilation, and had juft power enough to drop the mouth-piece from his unclofed lips. He was very ill and feeble after. He thinks it proves that hydro-carbonat acts as a fedative; *i. e.* it produces diminution of vital action and debility, without previoufly exciting. He thinks four or five infpirations inftead of three would have deftroyed life immediately, without producing any painful fenfation.

He attempted to refpire carbonic acid, not being then acquainted with the experiments of Rofier: he introduced into a filk bag four quarts of well wafhed carbonic acid, produced from carbonat of ammonia by heat (which is in a high ftate of purity, and readily effected), and after a complete voluntary exhauftion of his lungs attempted to infpire it. It produced a fenfe of burning at the top of the uvula. It was in vain to make voluntary efforts to inhale it; at the moment the epiglottis was raifed a little, a painful ftimulation was induced, fo as to clofe it fpafmodically on the glottis. Thus, after repeated trials, he was prevented from taking a fingle particle of carbonic acid into the lungs. Carbonic acid.

He tried to breathe a mixture of two quarts of common air and three of carbonic acid, without fuccefs, it being nonrefpirable. He found a mixture of three quarts of carbonic acid with feven of common air to be refpirable, and breathed it for near a minute. It produced a flight giddinefs and inclination to fleep. They however rapidly difappeared after ceafing to refpire it. Carbonic acid poffeffes no action on arterial blood: hence perhaps it's flight effects when breathed, mixed with large quantities of common air. It's effects are very marked upon venous blood.

Oxygen. The oxygen was procured from manganefe by heat. In refpiring eight or ten quarts, for the firft two or three minutes, he perceived no effect. Towards the end his refpiration became oppreffed, and he felt a fenfation as if he wanted frefh air, though but little of the oxygen had been confumed. In one experiment, when he breathed from and into a bag containing twenty quarts of oxygen for near fix minutes, his pulfe was not altered in velocity, but rather harder than before. He perceived no effects but thofe of oppreffion on the cheft. Watt had fufpected that the effects attributed to oxygen produced from manganefe by heat, in fome meafure depended upon nitrous acid, fufpended in the gas formed during ignition by the union of the oxygen of the manganefe, with nitrogen likewife condenfed in it; and in the courfe of his experiments on nitrous acid, Davy feveral times experienced a fevere oppreffion on the cheft and difficulty of refpiration, not unanalogous to that produced by oxygen, but more violent; which feems to confirm Watt's fufpicion.

Nitrous gas. Being refolved to endeavour to breathe the nitrous gas, he introduced 114 cubic inches of it into a large mercurial airholder: two fmall filk bags of the capacity of feven quarts were filled with nitrous oxyd. After a forced exhauftion of his lungs, his nofe accurately clofed, he

made three inſpirations and expirations of nitrous oxyd in one of the bags, to free his lungs as much as poſſible from atmoſpheric oxygen; then after a full expiration of the nitrous oxyd, he transferred his mouth from the mouthpiece of the bag to that of the airholder, and turning the ſtop-cock, attempted to inſpire the nitrous gas. In paſſing through his mouth and fauces it taſted aſtringent and highly diſagreeable, cauſed a ſenſe of burning in the throat, and a ſpaſm of the epiglottis ſo painful as to oblige him immediately to deſiſt. After moving his lips from the mouthpiece which he opened to inſpire common air, aëriform nitrous acid was inſtantly formed in his mouth, which burnt the tongue and palate, and inflamed the mucous membrane. He never intends again to attempt ſo raſh an experiment.

Moſt extenſive action of nitrous oxyd produces no debility.

He frequently reſpired nitrous oxyd mingled with different proportions of common air or oxygen, and the effects produced by the diluted gas were much leſs violent than thoſe produced by pure nitrous oxyd. They were generally pleaſant, the thrilling was not often perceived, but a ſenſe of exhilaration was almoſt conſtant.

Immediately after a journey of 126 miles, being much exhauſted from having had no ſleep the preceding night, he reſpired ſeven quarts of nitrous oxyd for near three minutes. It produced the uſual pleaſurable effects. He continued exhilarated for ſome minutes afterwards, and in half an hour found himſelf neither more or leſs exhauſted than before the experiment: he had a great propenſity to ſleep. He repeated the experiment four or five times the following week with the ſame effect. He had experienced no deciſive exhauſtion after the excitement, although he was ſtill far from being ſatisfied it was unanalogous to ſtimulants in general.

It occurred to him, that, ſuppoſing nitrous oxyd to be a ſtimulant of the common claſs, the debility produced in conſequence of exceſſive ſtimulation by a known agent,

ought to be *increafed* after excitement from nitrous oxyd.

He therefore drank a bottle of wine in large draughts in lefs than eight minutes (being accuftomed to drink only water), which intoxicated him. Having remained in a ftate of infenfibility for two hours and a half, he awakened with head-ach and painful naufea. His bodily and mental debility was exceffive, and his pulfe feeble and quick. He then refpired twelve quarts of oxygen for nearly four minutes; and he fuppofed he was fomewhat exhilarated. The head-ach and debility ftill continuing with violence, he refpired feven quarts of pure nitrous oxyd for two minutes and a half. He was unconfcious of head-ach after the third infpiration, and was exceedingly exhilarated. The next morning he was well. This proves that debility from intoxication was not increafed by excitement from nitrous oxyd.

To afcertain with certainty whether the moft extenfive action of nitrous oxyd compatible with life was capable of producing debility, he refolved to breathe the gas for fuch a time and in fuch quantities as to produce excitement equal in duration, and fuperior in intenfity, to that occafioned by high intoxication from opium or alcohol. To habituate himfelf to the excitement, and carry it on gradually, he was enclofed in an air-tight breathing box of the capacity of 9½ feet. Taking a fituation in which he could, by means of a curved thermometer inferted under the arm, and a ftop watch, afcertain his pulfe and animal heat, twenty parts of nitrous oxyd were thrown into the box; the fmell and tafte were immediately evident. In four minutes he felt a flight glow in the cheeks and a diffufed warmth over the cheft, though the temperature of the box was not quite 50°; his pulfe was 104 and hard, the animal heat 98°. In ten minutes the animal heat was near 99°; in a quarter of an hour 99.5°, and the pulfe 102, and fuller than

before. Twenty quarts more were now thrown into the box, and well mingled by agitation. In twenty five minutes the animal heat was 100°, pulſe 124. In thirty minutes twenty quarts more were introduced : his ſenſations were exhilaration, a generally diffuſed warmth, and a diſpoſition to muſcular motion and merriment. In three quarters of an hour the pulſe was 104, animal heat not 99.5°, the temperature of the chamber was 64, the pleaſurable feelings increaſed, the pulſe fuller and lower; and in about one hour it was 88, and the animal heat 99°. Twenty quarts more were admitted. He had now a great diſpoſition to laugh, luminous points paſſed before the eyes, his hearing more acute, and a pleaſant lightneſs and power of exertion were felt in his muſcles. The ſymptoms then became ſtationary, reſpiration rather oppreſſed, and from the great deſire of action reſt was painful. He now came out of the box, having been in preciſely one hour and a quarter.

He immediately began to reſpire twenty quarts of pure nitrous oxyd; a thrilling extending from the cheſt to the extremities was almoſt immediately produced; his pleaſurable ſenſations increaſed, he loſt all connexion with external things, and he exiſted in a world of newly connected and newly modified ideas. When awakened from this ſemidelicious trance by the bag being taken from his mouth, indignation and pride were his firſt feelings at ſight of thoſe around him ; his emotions were enthuſiaſtic and ſublime. Three minutes and a half had only elapſed during the experiment, but, from the relative vividneſs of the recollected ideas, it appeared much longer to him. Not more than half of the nitrous oxyd was conſumed. After a minute, before the thrilling of the extremities had diſappeared, he breathed the remainder. Similar ſenſations were again produced ; he was thrown into the pleaſurable trance, which continued longer than before. He

ate his dinner with great appetite, found himfelf unufually cheerful aud active at night, enjoyed profound repofe in bed, and awoke in the morning with confcioufnefs of pleafurable exiftence, which continued more or lefs through the day.

He has fince often breathed the nitrous oxyd, and his fufceptibility to it's power is rather increafed than diminifhed. He finds fix quarts a full dofe, but is rarely able to refpire it in any quantity for more than two minutes and a half. The mode of it's operation however is fomewhat altered, and is very different at different times. He is fcarcely ever excited into violent mufcular action; the emotions are generally much lefs intenfe and fublime than in the former experiments, and not often connected with thrilling in the extremities. When troubled with indigeftion, he was two or three times unpleafantly affected. Cardialgia, eructations, and unpleafant fulnefs of the head were produced. He has often felt great pleafure when breathing it alone, in darknefs and filence, occupied only by ideal exiftence. In two or three inftances, when breathed amidft noife, the fenfe of hearing has been painfully affected even by moderate intenfity of found. The light of the fun has fometimes been difagreeably dazzling. Whenever breathed after excitement from moral or phyfical caufes, the delight has been often intenfe and fublime.

Conclufion. From the facts already laid down, it appears that the immediate effects of nitrous oxyd upon the living fyftem are analogous to thofe of diffufible ftimuli: both increafe the force of circulation, produce pleafurable feeling, alter the condition of the organs of fenfation, and in their moft extenfive action deftroy life. In the mode of operation of nitrous oxyd and diffufible ftimuli, confiderable differences, however, exift. Diffufible ftimuli act immediately on the mufcular and nervous fibre: nitrous

oxyd acts upon them only by producing peculiar changes in the compofition of the blood. Diffufible ftimuli affect that part of the fyftem moft powerfully to which they are applied, and act on the whole only by fympathy with that part: nitrous oxyd, in combination with the blood, is univerfal in it's application and action.

As life depends immediately on certain changes effected in the blood in refpiration, and ultimately on the fupply of certain nutritive matter by the lymphatics, it is reafonable to conclude, that during the action of ftimulating fubftances, from the increafed force of circulation, not only more oxygen, and perhaps nitrogen, muft be combined with the blood in refpiration, but alfo more fluid nutritive matter fupplied to it in circulation.

By this oxygen and nutritive matter excitability may be kept up; and exhauftion, confequent to excitement, only produced, from a deficiency of fome of the nutritive principles, fupplied by abforption. Then nitrous oxyd is breathed; nitrogen (which in fluid compounds is carried into the blood by the abforbents) is fupplied in refpiration; a greater quantity of oxygen is combined with the blood than in common refpiration, whilft lefs carbonic acid and probably lefs water are evolved. Hence probably a fmaller quantity of nutritive matter is required from the abforbents during the excitement from nitrous oxyd, than during the operation of ftimulants; and, in confequence, exhauftion from the expenditure of nutritive matter more feldom occafioned.

He has lately endeavoured to afcertain the quantities of nitrogen produced, when nitrous oxyd is refpired for a confiderable time. In one experiment; when he breathed about four quarts of gas in a glafs bell over impregnated water for near a minute, it was diminifhed to about two quarts, and the refiduum extinguifhed flame.

Now his experiments prove, that, when nitrous oxyd is decompofed by combuftible bodies, the quantity of nitrogen evolved is rather greater in volume than the preexifting nitrous oxyd. Hence much of the nitrogen taken into the fyftem during the refpiration of nitrous oxyd muft be either carried into new combinations, or given out by the capillary veffels through the fkin. The various effects of nitrous oxyd upon different individuals, and upon the fame individual at different times, prove that it's powers are capable of being modified, both by the peculiar condition of the organs, and by the ftate of general feeling. It is probable that pleafurable feeling is uniformly connected with a moderate increafe of nervous action; and this increafe, when carried to certain limits, produces mixed emotion or fublime pleafure, and beyond occafions abfolute pain. From comparing facts, it is likely that individuals poffeffed of high health and little fenfibility will generally be lefs pleafurably affected by nitrous oxyd, than fuch as have more fenfibility, in whom the emotions will fometimes fo far enter the limits of pain as to become fublime; whilft the nervous action in fuch as have exquifite fenfibility will be fo much increafed as often to produce difagreeable feeling. Modification of the nitrous oxyd by oxygen or common air will probably enable the moft delicately fenfible to refpire it without danger, and even with pleafurable effects; in it's pure form the moft robuft are unable to refpire it with fafety for more than five minutes. Hyfterical affection is occafioned by it, probably only from the ftrong emotion produced deftroying the power of the will.

The quicknefs of the operation of the oxyd will probably render it ufeful in cafes of extreme debility, produced by deficiency of common exciting powers; and perhaps when mixed with oxygen or common air, it may

be ufed to recover perfons apparently dead from fuffocation by drowning or hanging, as by it's immediate operation the tone of the irritable fibre is increafed, and as exhauftion rarely follows the violent mufcular motions fometimes produced by it, it may be of ufe in fimple mufcular debility. As it appears capable of deftroying phyfical pain, it may be of ufe in furgical operations where no great effufion of blood takes place.

From the ftrong inclination of thofe who have been pleafantly affected by the gas to refpire it again, it is evident the pleafure produced is not loft, but that it mingles with the mafs of feelings, and becomes intellectual pleafure or hope. The defire of fome acquainted with the pleafures of nitrous oxyd has been fo great, as to induce them to breathe with eagernefs the air remaining in the bags after the refpiration of others.

As hydrocarbonat acts as a fedative, and diminifhes living action as rapidly as nitrous oxyd increafes it, it would follow, that by differently modifying the atmofphere by means of this gas and the oxyd, we fhould be in poffeffion of a regular feries of exciting or depreffing powers applicable to every deviation of the conftitution from health; but the common theory of excitability is moft probably founded on a falfe generalization. The modifications of difeafed action may be infinite and fpecific in different organs; and hence out of the power of agents operating on the whole of the fyftem.

Pneumatic chemiftry in it's application to medicine is an art in infancy, weak, almoft ufelefs, but apparently poffeffed of capabilities of improvement. To be rendered ftrong and mature fhe muft be nourifhed by facts, ftrengthened by exercife, and cautioufly directed in the application of her powers by rational fcepticifm.

Approximations to the compofition and weight of the

aëriform combinations of nitrogen at temperature 55° and atmofpheric preffure 30.

		100 Cubic Inches.		Grains.		Nitrogen.	Oxygen.
Nitrogen		Nitrogen	weigh	30.04	100 Grains are compofed of		
		Oxygen		35.06			
	With Oxygen.	Atmofpheric air		31.10		73.00	27.00
		Nitrous oxyd		50.20		63.30	36.70
		Nitrous gas		34.26		44.05	55.95
		Nitrous acid		76.00		29.50	70.50
						Nitrogen.	Hydrogen.
	With Hydrogen.	Ammonia		18.05		80.00	20.00

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Animalization. This is a proceſs which the animal machine makes uſe of to convert vegetable matters taken into the ſtomach for the ſake of nutrition into animal matter; and *aſſimilation* is the tranſlation of alimentary ſubſtances, whether produced from the vegetable or animal kingdom, into ſuch a ſtate as renders them ſimilar to the different parts of which they are to become a conſtituent part.

Animalization.

Aſſimilation.

Theſe proceſſes are ſuppoſed to be brought about by a chemical action; and perhaps amongſt all the operations which take place in the animal economy, there is no one that reſembles the chemical action more than that which

Suppoſed to be chemical proceſſes.

brings about the fucceffive changes aliments undergo, from the inftant they are received into the ftomach to the period at which, after having traverfed the organs of refpiration, they only form a part of one homogeneous fluid, the blood, in the fyftem of circulation, which is deftined for the nourifhing and the repairing of the different parts of the animal body. This converfion of aliment into an animalized fluid, afterwards deftined to form the various folids and fluids, is undoubtedly one of the moft beautiful, fingular, and interefting fubjects the living animal machine can offer to the inveftigation of the chemical phyfiologift, and is one of thofe which has always appeared to philofophers the moft myfterious to conceive, and the moft intricate to unravel, of any of the operations that animal life prefents.

It is but a few years ago fince it was even forefeen that the fcience of chemiftry would ever be able to furnifh any thing that could explain the operation of this function, by which the fucceffive and uninterrupted reproduction of all the parts of the body is brought about. It was neceffary that the nature of the atmofpheric air fhould be underftood, the office of refpiration be known, and the analyfis of animal matter and it's effential difference from vegetable matter fhould be clearly indicated; thefe points being once determined, there was much lefs difficulty in concluding in what confifted the affimilation of aliments, and this has been effected by the new fyftem of chemiftry; but it will be neceffary firft to give an account of the idea the defenders of the old fyftem had conceived of animalization, in which phlogifton formed as ufual a confpicuous part.

Opinion of Ker.

Ker, the ingenious author of the Dictionary of Chemiftry, appears to have formed his idea of animalization from Macquer, who confidered the converfion of vegetable matters into animal to be principally effected by

means of a fermentation, or the beginning of a long and unobservable putrefaction, and which originated in the conjectures of Hippocrates and Empedocles.

This chemist has, however, greatly enlarged the plan, and improved the hypothesis of his predecessors. He is of opinion, that when vegetable substances are received as food into the bodies of animals, the changes they undergo, and elaboration they suffer by the animal powers, is a chemical process, which process appears to be *a continually commencing putrefaction, continually checked and subdued.* The signs of this commencing putrefaction, he affirms, are the expulsion of fixed air, the black colour the venous blood acquires, the more disengaged state of phlogiston in animal bodies than in vegetables, whence they receive their food, their greater putrescency, their disposition to give in great quantity volatile alkali by distillation, and phlogisticated air by addition of nitrous acid, which substances are known to be products of putrefaction. Is an incipient putrefaction.

This putrescency, however, appears to be confined within limits, during life, contrary to the known tendency of animal matters deprived of life, which hasten rapidly to putrefaction; that the vital counteracting causes by which the natural tendency of *animal* matters to putrefaction is continually checked, is owing, in some measure, to the frequent ~~indigestion~~ digestion of fresh food, especially of vegetables; but as many animals are known to live solely on animal food, and this often in a putrid state, whilst they enjoy health and soundness, there must be another principal cause to be equivalent to so great and uniform an effect, which this chemist affirms to be the *absorption of air by the lungs.* It is observed, that the expulsion of pure air in the form of fixed air, and of a disengaged phlogiston in the form of inflammable gas, are the most considerable phenomena in respect to quantity and dura-

tion, which appear in the putrefactive procefs. In the fame manner, the expulfion of pure air in refpiration, in the form of fixed air, and the confequent predominancy and difengagement of phlogifton in the body, is the actual ftate of the animal procefs. If this predominant phlogifton were not conftantly combined with the pure air, which is abforbed by the lungs in refpiration, it would proceed as it does in the putrefaction of matters not in living animals, *i. e.* it would form inflammable gas, and phlogifticated air, and act as a ferment in haftening the putrefactive diffolution. The very remarkable effect of inflammable gas in promoting the putrefaction of animal bodies immerfed in it, is fhown by an experiment defcribed by Sage in the Mem. de l'Acad. Roy. des Sc. à Paris, An. 1784; and although it is probable the difengaged phlogifton would, if not combined with infpired pure air, occafion death by fome immediate action on the nervous fyftem, yet the livid hue obferved in men in afphyxy, or fuffocation from foul air, fhows that the blood fuddenly fuffers a chemical alteration.

Difengagement of phlogifton.

Putrefcency oppofed by pure air.

Pure air then, according to Ker, is no fooner abforbed than it gives immediate figns of counteracting the firft indications of putrefcency, which appear in the dark colour of the blood brought into the lungs, by inftantaneoufly changing this colour to a vivid hue. This change of colour from a dark red or black to a florid red, exactly correfponds with the known effects of the different fluids upon the colour of blood. For a dark livid colour is produced by expofing blood out of the body to inflammable gas, fixed air, or phlogifticated air, and a florid red hue is given to blood by pure or atmofpherical air. The experiments which have been made by expofing blood to pure air, befides prove, that this fluid has a remarkable power of abforbing this air. Putrefying fubftances have the fame power; for Dr. Prieftley obferved, that they

diminifhed the bulk of the mafs of air to which they were expofed, notwithftanding fubftances in that ftate emit fixed air and inflammable gas. It is by means of this conftant counteraction of the putrefcency of the blood, according to Ker, that opportunity and time are given for various other gradual changes, combinations, and decompofitions to take place; in confequence of which changes the different animal fluids may be fuppofed to be formed. Thus he conjectures the red part of the blood is firft formed in a great meafure from the chyle, both being of an oleaginous nature; but with this difference, that the oily matter in the chyle is imperfectly mixed, and confequently gives the ufual opake whitenefs mixtures of oil and water generally exhibit; whereas the oil in blood is more perfectly combined with earthy matter, probably by abforption of pure air in refpiration. It may be remarked, that thefe two animal liquors, the chyle and the red blood, contain particles vifible by means of the microfcope. But a more conclufive operation has been taken notice of, viz. that one of the moft immediate effects of famine is to diminifh the proportion of the red blood. The fuperfluous oil of the chyle is feparated and depofited in proper cells, without undergoing much alteration. For the tallow of animals which live on vegetables retains the properties of vegetable oils, particularly that of making *hard* foap with mineral alkali; whereas the greafe of carnivorous animals, and the oil of fifh, feem altered by the animal procefs, and are capable only of making a *fofter* foap. The red particles of the blood, having a fufficient proportion of phlogifton in their compofition, are more difpofed than the other parts of the blood to putrefcency: accordingly, as their phlogifton gradually leaves them, principally to form the fixed air extricated by the lungs, their proportion of the other elements increafes, *i. e.* they are gradually refolved into a

Formation of different parts.

compound containing lefs phlogifton, but more earth, water, and air; which compound this chemift conceives to be the coagulable part of the ferum, which being foluble in water, mixes with the watery particles received with the food, and forms the ferum. In confequence of the dephlogiftication of the red blood, by which it is thus fuppofed to be converted into the coagulable matter, this matter poffeffes lefs putrefcency, has even fome acefcent tendency, and when diftilled, leaves a more earthy and lefs inflammable coal. Some particles of this matter are denfer and more eafily coagulable than others, and thofe which coagulate with the leaft cold, have been called the *fibrous part* of the blood, and are found to invelop the red particles, when blood let out of the veins is cooled. As this matter is thus formed by the decompofition of the red blood, in the circulation, the more the force of the circulation is increafed, the more the particles in the blood will be agitated and brought into contact, the more this decompofition will be accelerated, and the larger quantity of this coagulable matter will be formed, a good deal of which will be of the denfer kind, till the continuance of the fame caufes refolves it into other fluids lefs denfe. For this matter alfo, according to this chemift, although lefs putrefcent than the red blood, neverthelefs undergoes gradually it's peculiar changes and decompofitions, by which more of it's phlogifton is evolved, and the remaining elements, earth, air, and water, being in greater proportion, approach more to a faline ftate, and at laft are excreted principally in the form of phofphoric falts, with bafes of calcareous earth, fixed and volatile alkali; which accordingly appear in the urine and other excretions, efpecially after an increafed circulation. As the changes of the blood are progreffive, the juices muft, at different times, affume a variety of forms, and in thefe different ftates, they may be fecreted

by organs fitted for their peculiar ſeparations by the diverſity of the diameters of the ſecretory veſſels, as ſome authors have conjectured with much plauſibility, or other appropriated mechanical ſtructure.

The *gluten* of the flour of wheat ſeems to be ſimilar to the more denſe coagulable matter of the blood in it's texture, it's degree of ſolubility in water, and in the products it yields by expoſure to diſtillation, viz. volatile alkali and phoſphorus. In ſome animals, as the teſtaceous, a part of the earth in their compoſition is entirely ſeparated from the other elements, and appears in it's proper ſtate, forming together with ſome portion of animal gluten the ſhells of theſe animals. A ſimilar kind of glutinous ſubſtance is formed by the ſpontaneous decompoſition, to which oily vegetable acids, as cream of tartar and common vinegar, are ſubject. The tenaceous cruſt then formed poſſeſſes the ſame texture and chemical qualities as animal or farinaceous gluten. Laſtly, the *caſeous* part of milk poſſeſſes the ſame properties. In theſe ſeveral animal and vegetable glutens, the earth appears to be the prevalent element in the compoſition, and their formation ſeems to conſtitute one of the more advanced ſtages in the gradual changes which take place in organic bodies. Such is the opinion of this learned chemiſt reſpecting the proceſs of animalization.

The new doctrine of chemiſtry, ſo inimical to the phlogiſtic ſyſtem, has equally changed the method of explaining the phenomena of animalization, as well as that of other proceſſes, and has ſubſtituted in it's place a theory that is much better ſuited to the facts that have been collected upon that vital function, and to the analyſis of the ſubſtances that are it's objects, than what could have been done by the old theory. **Opinion of Halle.**

From the experiments of Berthollet, we are indebted for the diſcovery that it is principally by the preſence of

azot that the matters of the animal kingdom differ from the vegetable; it is therefore neceſſary firſt to know, in explaining this ſubject, by what means azot is found more abundantly in animals, and this being once accounted for, will form the baſis of our knowledge on animalization. It may be eaſily conceived that the difficulty of acquiring this knowledge can only relate to thoſe animals that live on vegetable matter, for the origin or the ſource of that principle in thoſe animals that feed on the ſame food as themſelves are compoſed of, *i. e.* on animal food, needs no inveſtigation.

For the attempt to explain the function of animalization upon antiphlogiſtic principles, we are indebted to Halle, who has collected a number of new truths from the labours of modern chemiſts, and formed a theory on the influence of the air in the operation by which the aliments are converted into animal ſubſtances.

Having introduced his ſubject with ſome account of the analogies that ſubſiſt between vegetable and animal matters, particularly between vegetable gelatin, and gluten and animal gelatin, and fibrin, which are the principal parts, and thoſe which form with the phoſphat of lime the moſt univerſal baſis of animal ſolids; he goes on by obſerving, that there is a character of reſemblance much more important, and for the knowledge of which we are principally indebted to Berthollet. It is, that all vegetable and animal ſubſtances ſerving us for food, and all of thoſe compoſing our own ſolids and fluids, except a very few, have one common baſis in their compoſition, which is differently combined, according to the diverſity of theſe ſubſtances, and which is ſuſceptible of changing their combination by a great number of different operations. This common baſis is that of the oxalic acid, *i. e.* that ſubſtance which combined with oxygen, the principle that forms acids, gives riſe to the acid, formerly called

Analogy between vegetable and animal ſubſtances.

Have one common

saccharine acid, but now known by the name of *oxalic acid*. bafis, the oxalic acid.

This bafis is that of all nutritive fubftances in general. The faccharine matter, the mucilage, the fecula, the gelatinous and mucous juices of vegetables, the vegetable gluten, a great number of vegetable acids, and likewife all animal mucilages; their jellies, their fibrous part, their albuminous fubftance, and the cafeous part of milk, have all of them the fame principle for a bafis, which is that of the oxalic acid. This is proved by the nitric acid.

Likewife, the fat oils of vegetables, the butters, and the animal fats, the analyfis of which does not afford exactly the fame refult, appear, as is attefted by feveral phenomena of the animal economy, to be capable of being transformed into this bafis, and from the knowledge that has been acquired on the ftate of this ifolated oxalic bafis, there is reafon to prefume, that if there be not a perfect identity between it and the fat oils, there is only a difference in the combination, the nature of which Lavoifier appears to have nearly determined: this chemift afferts, that this bafis, as well as the oils, is formed of hydrogen and carbon, but both in the ftate of oxyds, and which confequently is the point of refemblance between all fubftances capable of affording nourifhment.

Such is the analogy. As to the difference, we are indebted for this part of the analyfis to Berthollet, who, pursuing the fteps of Bergman and Scheele, has been able to demonftrate the different principles to which the oxalic bafis is combined, both in animal and vegetable fubftances, whilft Fourcroy has likewife contributed to augment the knowledge this important analyfis has procured us. Difference between them.

The oxalic basis combined with carbon in vegetables, with azot in animals.

It is demonstrated by the labours of the above chemist, that in all these substances, the oxalic basis, without changing it's nature, is more particularly combined with two different principles.

1. With the principle of charcoal or *carbon*, the same which, when combined with the basis of vital air, forms carbonic acid.

2. With one of the constituent principles of volatile alcali, or *azot*, which forms the basis of azot gas.

The first, or carbon, is more abundant in vegetable substances; the second, or azot, is found in greater proportion in animal substances. Those which contain carbon in great abundance, and little or no azot, are likewise those which in their spontaneous decomposition give early signs of acescence; those, on the contrary, which contain a great portion of azot, become suddenly alcalescent.

Thus when vegetable substances become animalized, and when our aliments, which are in general less animalized, than ourselves, are assimilated to our own substance, it may be said the change which then takes place in them consists for the most part in their oxalic basis combining with a greater proportion of the basis of azot gas, or *azot*; whilst on the contrary, it loses a part of the principle of charcoal, or *carbon*, to which it might be united: on considering, therefore, that on analysis, if either the one or the other of these principles be separated from the oxalic basis to which they are united, the combinations into which they pass, almost always give rise to some elastic fluids; it will be readily conceived, how much the consideration of these fluids in the animal economy ought to attract the attention

of phyficians, and how it may facilitate the knowledge of the moft important phenomena of our functions.

Halle having compared, in the manner above mentioned, the different fubftances that enter into the compofition of our aliments, and into that of our organs, which he calls the firft order of facts, continues the fubject by the fecond order of facts, comprehending

First and fecond order of facts.

1. The ftate of the elaftic fluids contained in the alimentary canal.

2. The changes the air undergoes during refpiration.

3. The alterations it undergoes in it's contact with the fkin.

With refpect to the *firft*. This chemift informs us, the obfervations which Jurine of Geneva made on the ftate of the elaftic fluids contained in the inteftinal canal, were formed from fome experiments made on a ftrong hearty perfon who had died fuddenly during a cold night, and which were compared with thofe the diffection of feveral other bodies offered, under different circumftances, but who died in good health.

Thefe experiments prefent thefe remarkable refults, that of the elaftic fluids contained in the inteftinal canal, 1. The refpective proportion of vital air always diminifhes progreffively from the ftomach to the great inteftines: 2. The refpective proportion of azot gas always increafes progreffively from the ftomach to the great inteftines: 3. The proportion of the hydrogen gas in general augments from the ftomach to the fmall inteftines, and diminifhes from them to the great inteftines: 4. The proportion of carbonic acid gas is the moft variable of all in different fubjects; it was very ftrong in the ftomach of the fubject that died fuddenly, but very weak in the reft of the inteftinal canal: 5. It appears that there exifts a little alcaline or ammoniacal gas in the canal of the laft inteftines.

Such is the refult of thefe experiments, made by lime water and the nitrous gas.

With refpect to the *fecond*, it was remarked by Prieftley, that refpiration produced azot gas. Lavoifier and de la Place proved, that during that procefs, carbonic acid gas was formed at the expenfe of the vital air, and the experiments were repeated by Jurine. Hence it appears that refpiration alters the atmofpheric air in three manners. 1. The portion of vital air, which makes a little more than one quarter of this fluid, is fenfibly diminifhed. 2. Carbonic acid gas is formed in proportion to this diminution of vital air. 3. A new quantity of azot gas is formed, which ought not to be attributed folely to the change in proportion between the two conftituent parts of the atmofphere, but which is, in reality, an additional quantity. Thefe alterations in the refpired air do not all take place in the fame inftant of time. The two firft, which are abfolutely fimultaneous, firft take place, as they depend entirely upon each other. When the portion of vital air in the refpirable air diminifhes, the quantity of carbonic acid produced by refpiration diminifhes likewife; but on the contrary, the difengagement of azot gas progreffively increafes, and augments the more, as there is lefs carbonic acid formed, fo that the firft portions of vital air appear to be employed in difengaging the carbonic acid, whilft the laft are difengaging the azot. This effect not only takes place in the ordinary atmofpheric air, which naturally contains more than two thirds of azot gas, it equally takes place in vital air, where the production of azot gas can only be the product of refpiration. It has likewife been obferved, that in the action that finifhes digeftion, the refpired air received a greater proportion of carbonic acid, and on the contrary, in the action of fever, it received a greater proportion of azot gas.

Laftly, with refpect to the *third*, Jurine has put it out of all doubt, that during the contact of the fkin with the external air, carbonic acid is formed, and that more is formed in proportion to the greater activity of the functions of the cutaneous organs. When the experiments of Jurine are compared with the manner in which Ingenhoufz made his obfervations on the fame fubject, it is eafily perceived how the refults obtained by thefe two philofophers may be perfectly reconciled, and upon what the difference depends that exifts between their conclufions. It is evident that to the manner in which Ingenhoufz made his experiments the difappearance of the carbonic acid was owing.

3. Halle, after having thus cited the above general facts, lays down the confequences refpecting the affimilation of the aliment. He obferves, that after having remarked, that the oxalic bafis, the common principle of almoft all nutritive fubftances, as well as of thofe that compofe our organs, is principally combined, in the one, with the bafis of carbonic acid or carbon, in the other, with the bafis of azot gas, or azot, and that the proportion of this laft formed one of the principal characters of animalization; the next circumftance is to confider the manner of their feparation.

Confequences deduced from them.

It is well known there are different ways of feparating thefe two principles from the oxalic bafis with which they are united, whether in our aliments or in our organs. That this feparation is principally brought about by the aid of bodies containing the bafis of vital air, viz. oxygen.

In the common chemical analyfis of fubftances the nitric acid is ufed to furnifh this bafis with more facility.

Separation of the different bafes by oxygen.

In the grand operations of nature it is furnifhed by the atmofpheric air, and by water. Wherever it is the atmofpheric air that difengages the carbon, carbonic acid is formed, or if it difengages the azot, azot gas. Wherever it is water that furnifhes the bafis of vital air, hydrogen

gas is difengaged; and wherever hydrogen is difengaged at the fame time as azot, and combines with it, ammonia or volatile alkali is produced.

The feparation being well underftood, the next is to examine what paffes in the human body.

Proportion of vital air in the inteftines.

In the inteftinal canal the proportion of vital air diminifhes fucceffively from the ftomach to the extremity of the inteftinal canal, and at this extremity there is no trace of it; thus the vital air, or it's bafis oxygen, forms combinations in this paffage, and what is the confequence?

It's combinations.

In the ftomach, where the aliments ftill poffefs their former properties and mix with the juices, of the nature of which there is much incertitude, a portion of *carbonic acid* is difengaged; the principle, carbon, that unites with the vital air to form this gas, appears to come from the aliment, and if the proportion be not conftant, it arifes from the aliments not always being the fame.

In the fmall inteftines into which the bile, one of the known humours that carries the moft evidently the animal character, flows with feveral other fecretions, and where the aliments, intimately penetrated with thefe humours, form a very liquid mafs, azot and hydrogen gafes are difengaged. One part of the matters contained in this canal being of the number of thofe that contain the bafis of azot gas or azot, may confequently give rife to the extrication of the azot gas, and thefe fame matters forming a heated mafs and in a liquid ftate are the beft adapted to bring about the decompofition of the water. The water being thus decompofed gives rife to inflammable gas, and at the fame time furnifhes the mafs of animal juices and aliments with a portion of the bafis of vital air or oxygen, which forms a combination whilft the azot efcapes.

Laftly, in the great inteftines, where the excrementitious mafs, by it's odour and products, announces the animal character, the quantity of azot gas increafes, but

the inflammable gas diminifhes a little, either becaufe the matters being lefs liquid favour lefs the decompofition of water, or becaufe a part of the hydrogen combined with the azot forms ammonia or alkaline gas; on the contrary, in certain diarrhœas, the air let loofe from the rectum bearing an hepatic odour, is a proof that a very large proportion of fulphurated hydrogen gas is formed in the great inteftines. But thefe matters being then more liquid, the decompofition of the water continues to take place beyond the fmall inteftines.

Thus in the alimentary canal the vital air, whether it be free and arifing from the atmofpheric air fwallowed with the aliments, or difengaged afterwards by the decompofition of water, combines both with the animal fecretions and with the aliments confounded with them in the inteftinal canal, and at firft feparates from the alimentary matters a portion of their carbon, with which it unites to form the carbonic acid, afterwards difengaging azot from the inteftinal fecretions, it favours it's combination with the alimentary matters that receive it in *lieu* of the *carbon*, a portion of which they have loft. In this manner the aliments that nourifh us commence their incipient animalization, the degree of which, Halle is of opinion, might be eftimated, if the nature of the chyle, which is the refult, was perfectly underftood.

4. Conclufion. It appears therefore to this chemical phyfiologift, from what has been above ftated, that a great part of the procefs producing the affimilation of aliments, is performed in the *inteftinal canal*, in the *organs of refpiration*, and upon the *furface of the fkin*. That in thefe three organized parts, the atmofpheric air, and particularly the vital part of this air, is the principal inftrument of the combinations by which the affimilation is brought about; that it probably acts by taking away from the alimentary matter a portion of it's carbonic Conclufion.

principle, and by facilitating it's combination with the overplus azot of the animal humours, and consequently, that in this common operation, the execution of which is divided between three different organs, but founded in all upon the same principles, a reciprocal change takes place at the same time, as well in the substance of the aliment as in that of the animal humours; by which the one being animalized, and the others losing, as it were, the excess of their animalization, all of them are brought to the same point, and appear mutually assimilated.

Imperfection of this theory.

This chemist, in delivering his theory to the world, does not presume to think that it explains the formation of all the products of animal assimilation, he allows, it neither accounts for the production of the phosphoric salts, nor that of the fat matter analogous to spermaceti, found by Fourcroy in the liver and bile; nor does it explain the manner in which the other animal products are modified, on which modern chemistry has at present cast no light; hence it is incomplete. Such is the manner by which Halle has attempted to explain the mechanism of the assimilation of aliments, and of the change they undergo in their nature, and in which it is to be observed, that although he has made use of the discoveries of Scheele, Bergman, Lavoisier, Priestley, and Berthollet, yet he is one of the first that has embraced so great an extent of operations at the same time respecting the animal functions, and that it was impossible from the present state of facts, that so difficult a problem as that of animalization could be resolved by the few materials he was in possession of.

Observations of Fourcroy upon it.

Fourcroy, who had perhaps a better opportunity of becoming acquainted with facts than Halle, and who had the advantage of later discoveries, has made some restrictions and observations upon the hypothesis of the latter. He thinks it necessary to observe, that in referring all substances composed of the vegetable and animal

kingdom to what Halle calls the *oxalic basis* or *oxalic radical,* this philosopher could only have in view the fixing a striking analogy between all substances; but as the considering of it in this light without some modifications might lead to errour, it is necessary to explain how far the truth is able to carry us.

By the oxalic basis or radical is understood a matter composed of hydrogen and carbon, which when united with a large proportion of oxygen, gives rise to the oxalic acid, and which plays the same part in this acid as sulphur, phosphorus, charcoal, or arsenic does in the sulphuric, phosphoric, carbonic, and arsenic acids. If all animal and vegetable matters can be considered as the oxalic basis, it can only be as containing the *carbonated hydrogenous* combination constituting this basis. But it would be erroneous to suppose that this *carbonated hydrogen* is equally composed, as to the proportion of these two principles, and consequently equally ready to form the oxalic acid on the addition of oxygen, in all these matters. On the first part.

The combination of hydrogen and of carbon that forms the general basis of organized substances is not homogeneous in all of them; it differs either in the proportion of one or other of the primitive principles, or in the addition of a greater or less quantity of azot, or lastly, in the proportion of the oxygen it already contains; hence to be converted into oxalic acid, it is not sufficient constantly to add oxygen and an equal quantity of oxygen to it. For the one it is necessary that a certain proportion of hydrogen or carbon be disengaged, according as the one or the other exceeds the quantity that ought to form the true oxalic radical; for the other to disengage a portion of these two principles; for a third order of these substances to take away or separate at first the azot that does not appear to enter into the oxalic acid. Thus,

when by means of the nitric acid, the gums, fugar, or ftarch, are converted into oxalic acid, much carbonic acid is difengaged, becaufe thefe matters contain much more carbon than is neceffary for the oxalic radical; when by means of the fame nitric acid the fame procefs is applied to the oils, butters, fats, refins, &c., a great deal of hydrogen and carbonic acid gafes is difengaged, a proof of there being more hydrogen and carbon than are neceffary for the oxalic radical; laftly, when the nitric acid is made to act on vegetable gluten, elaftic gum, mufcular flefh, and all other animal matters, thefe matters are not converted into oxalic acid until they have given out azot and carbonic acid gafes, becaufe they contain azot that does not enter into the formation of the oxalic acid, and more carbon than this acid has need of: and it is in this manner the nature of the oxalic radical is to be looked upon, as far as Halle conceives it to exift in all matters confidered as aliments, whilft what has been faid upon the fubject ought only to refer to the following propofition, viz. that all alimentary matters contain that, which, by the addition of oxygen, forms the oxalic acid.

On the fecond part. Since the facts related by Halle on refpiration, that function has been much better inveftigated by the united labours of Lavoifier and Seguin. During refpiration, water is undoubtedly formed, and there is a difengagement of hydrogen as well as of carbon from the blood. This effect refembles that which takes place in all vegetable matters expofed to the air. It even appears to Fourcroy, that hydrogen burns more eafily than carbon, at leaft in making the analogy refpecting vegetable fubftances. He allows, however, that this formation of carbonic acid and water during refpiration is not as yet fupported by any pofitive experiments. There are even fome who think that the vital air is wholly abforbed by

the lungs, that in the courfe of circulation it is by degrees converted into carbonic acid, and that it is afterwards evacuated by the lungs. This opinion, it is evident, is very different from that which explains the formation of the carbonic acid to be effected by the pulmonary organ, owing to the carbon difengaged from the blood afterward uniting with the atmofpheric oxygen. The obfervation upon what paffes during the refpiration of the great grafshopper (locufta vermivora of Geoffroy) by Vauquelin, appears to authorize this laft opinion. He found a canal which conducts the air immediately from the trachea to the ftomach, and he believes with much probability, that the air ferves to the affimilation of the aliments. If the immediate combination with the mafs of aliments or of the chyle be neceffary to complete digeftion, or to affimilation, as fome facts appear to indicate, and as feveral philofophers are of opinion, it appears that the vital air really penetrates the lungs and combines with the blood, which at the fame time exhales carbonic acid. To conclude, it is fufficient for the conclufions drawn by Halle in whatever manner thefe things are effected, that there be fome means during refpiration of exhaling carbon. Lavoifier has confirmed, by his laft experiments on refpiration and tranfpiration, the refult of thofe of Jurine, and it appears inconteftibly, according to Fourcroy, that the procefs which takes place on the fkin affords a fimilar phenomenon to what paffes in the lungs, *i. e.* a formation or a difengagement of carbonic acid. It may be poffible that three effects concur at the fame time in this procefs of affimilation, for which it is proved that the pulmonary and cutaneous organs are in a great meafure deftined. Perhaps there is a feparation of carbon and hydrogen from the lungs; perhaps oxygen may penetrate at the fame time, which uniting by degrees with the carbon of the blood during refpiration, after-

ward flows out in torrents through the veſſels of the whole ſurface of the ſkin. (*Vide* reſpiration.)

On the third part.

Fourcroy is of opinion that Halle, in attributing the beginning of aſſimilation brought about in the ſtomach and inteſtines in great part to the decompoſition of water, cannot ſupport his conjecture; and indeed, it is only upon the preſence of carbonic acid, hydrogen, and ammoniacal gaſes in the cavity of theſe viſcera, that he offers it. It is neceſſary to remark, that it is founded upon an obſervation made by Jurine only on one caſe, and that it would not be reaſoning with much preciſion to apply it as a general rule. It may be preſumed, that the exiſtence of the gaſes is nearly the ſame in the courſe of the alimentary canal of all ſubjects with that which Jurine found in his ſubject; but there is no proof that the production of theſe inteſtinal gaſes are owing to the decompoſition of water, nor even that the difference of theſe gaſes in the different parts of the canal depends upon the ſtate of the water.

Fourcroy's explanation.

Fourcroy is of opinion, that the primary effects of digeſtion, which ought not to be confounded with thoſe of aſſimilation, properly ſo called, may be explained without having recourſe to the decompoſition of water. Four principal phenomena take place in the aliments during their reſidence in the ſtomach and inteſtines.

1ſt. The aliments are ſoftened and diſſolved into a kind of homogeneous pulp in the inteſtines.

2d. Their character is changed by the gaſtric menſtruum.

3d. This ſolution is decompoſed in the ſmall inteſtines by the bile, which ſeparates the alimentary part from the excrementitious.

4th. The chylous matter is abſorbed by the lymphatics in the large inteſtines, and the excrementitious matter is forced down, carrying with it the fat and colouring matter

of the bile. The bile conveyed into the blood undergoes a change in the lungs. The aliments themſelves may be the ſource of the gaſes contained in the alimentary tube.

This chyle being poured into the blood, and mixed with it as the alimentary matters were mixed with the animal ſecretions in the inteſtines, is then acted upon by means of reſpiration. During that proceſs, the vital air forms combinations, carbonic acid and azot are diſengaged, but both do not appear internally at the ſame time. The azot gas only appears when the quantity of carbonic acid formed by the vital air, and mixed with the reſpired air, diminiſhes in this air the property of diſengaging freſh acid from the lungs, which is the caſe when bad air is breathed. Then the azot, which is probably alſo diſengaged, but which combined with the chyle in proportion as this loſt it's carbonaceous principle, finding no more to combine with, departs with the air in the form of gas.

It is therefore probable that in this caſe the principle of the carbon is furniſhed by the chyle, and the azot by the blood, and that a real exchange is made as in the proceſs of digeſtion, *i. e.* the chyle, on loſing a part of it's carbon, receives in *lieu* of it the azot ſeparated from the blood, and by this mechaniſm is animalized and aſſimilated. It may be ſaid that the blood likewiſe aſſimilates itſelf, becauſe without this exchange, which deprives it of an exceſs of azot, it would be too much animalized, and at laſt become alkalized, which, in effect, always takes place when a long abſtinence, or food which is too much animalized, prevents the humours from receiving their neceſſary temperature by the mixture of a mild chyle.

It may be aſked, if the reſpiration would ceaſe to pro-

duce carbonic acid gas, in confequence of a long faft, and at laft only produce azot gas, which would feem to be the confequence of this fyftem. Experiments are wanting to anfwer this queftion; but prefumption, and two facts ftated by Jurine, almoft affure the affirmative. The one proves, that in the procefs that follows the digeftion of the aliment, and which is accompanied by a fenfible increafe of heat, and an accelerated pulfe, the proportion of carbonic acid formed by the refpiration in equal quantities of air, is much greater. The other ftates, that in fevers, the contrary takes place, for the proportion of carbonic acid is diminifhed, and that of azot gas increafed.

After this important operation, follows that which is the refult of the functions of the fkin. From the furface of this organ, the vital air likewife difengages a portion of the carbonic principle, with which it forms carbonic acid; and if it be true, as an experiment of Dr. Prieftley appears to prove, although contradicted by thofe of Cruickfhanks and Jurine, that the air which has remained in contact with the fkin appears, on trying it with nitrous, to be meliorated, and to have loft during this contact a part of it's azot gas, the confequence would alfo be, that the humours become animalized in the fkin by a mechanifm analogous to thofe of digeftion and refpiration; at leaft it appears certain, that a difengagement of the carbonaceous principle really takes place in this organ, but the ignorance which covers the real nature of cutaneous perfpiration, ftill involves this fubject in obfcurity. *Vide* Refpiration.

Such are the modifications made by Fourcroy on the fyftem of Halle, and the obfervations which the ftate of the fcience allowed him to make on the procefs of animalization. The facts which have fince been brought to

light, are very few, and are fcarcely fufficient to afford any further explanation than what this chemift has given us; before, however, this article is concluded, it will be neceffary to mention the little that remains. Conclufion.

Opinion of Parmentier and Deyeux.

It is the opinion of feveral of the moft celebrated chemifts, and particularly of Parmentier and Deyeux, that the different folids and fluids of the body are created by the procefs of animalization from the remote, and not from the proximate parts, and confequently, that the vital organization does not take from the aliments albumen, gelatin, fibrin, fulphur, phofphorus, foda, lime, or iron, all of which they look upon as compofitions, but only their ultimate parts which are neceffary for their formation.

Thus, in the blood, the different fubftances it contains are not extracted immediately from the aliments, fince in fpite of their infinite variety, this fluid, whatever be it's origin, conftantly furnifhes the fame principles on analyfis, and they even appear fo neceffary to it's compofition, as not to be able to exift without them. Hence thefe chemifts think, that it will be ufelefs in future to endeavour to fearch in aliments and drinks for fuch of their parts as ought to ferve in the formation of the chyle, the blood, bile, &c., or to pretend to give a reafon for the transformation of the one into the other, without changing their nature. Before undergoing this transformation, it is neceffary for thefe fubftances to be expofed to the action of the ftomach and inteftines, to pafs through all the periods of decompofition, and that the gafeous materials, or aëriform fluids arifing, undergo a certain fabrication in the different organs, fo as to form the various matters of the body, with modifications peculiar to each individual fpecies, according to it's phyfical conftitution, whether healthy or vitiated by fome morbific affection.

Other opinions.

It has already been afferted, that the remote parts of animal fubftances are reduced to nine, viz. azot, oxygen, hydrogen, carbon, foda, fulphur, phofphorus, lime, and iron, and that the principal difference between animals and vegetables confifted in the prefence or proportion of azot, which the firft contained in fuch large quantity.

It might therefore be concluded, that the grand procefs of animalization confifted in the fixation of azot, and the addition of it as the principal phenomena of animal organifm; but it has been obferved by the lateft phyfiological chemifts, that this phenomenon ought not to be confidered fo much the effect of the fixation of a new quantity of this principle, as the fubtraction of the other principles, by which the proportion of the firft muft be in confequence increafed. It is thus, for inftance, that the function of refpiration, by gradully difengaging a great quantity of hydrogen and carbon, which, by uniting the one with the oxygen to form water, the other with another portion of oxygen to form carbonic acid, muft neceffarily increafe the proportion of azot. A large proportion of this principle being thus accumulated, is ready to be united with more or lefs of the other remote parts in different proportions, to form the various animal fubftances of which a body is compofed.

Humboldt.

According to Humboldt, this union by the function of animalization is brought about by the intermedium of the galvanic fluid. Thus the carbon and hydrogen, combined by means of this galvanic fluid, form oils. The hydrogen and carbon, combined with the oxygen by the fame means, form acids. The hydrogen, combined with the azot, forms foda, and fo of the compofition of the reft of animal fubftances, all being formed by the intervention of this fluid, the nature and properties of which are at prefent not underftood, although this chemift looks upon it to be the nervous fluid. With refpect to lime

and iron, he does not confider them as new products in the animal body, but as furnifhed by the aliments. De la Metherie, however, as well as feveral other chemifts, affirms, that the vital power is able by certain organized parts to form thefe two fubftances as well as fulphur and phofphorus, and of courfe that they are as well as foda compofed of remote parts; and this conjecture is rendered very probable by feveral late experiments: thus Vauquelin found, that the formation of both lime and phofphorus was effected by the function of animalization in the hen (*vide* Fœces), and the large quantity of the phofphat of lime found in milk, and the fhells of all animals, which cannot be accounted for by any other means, appears greatly to fupport the hypothefis, that it is the product of the vital powers; whilft Fourcroy attributes the abfence of the phofphoric acid in the blood of the fœtus to the want of refpiration. With refpect to foda, it is only by the fame way of explanation that it's prefence can be accounted for in graminivorous animals; and as to fulphur and iron, there is great fufpicion that they are of the fame manufactory, and fabricated by the fame powers applied to a different organization. The fame may be faid of the acids, &c.

Hence it appears, that the organifm neceffary to animalization has the power of reducing aliments to their remote component parts, and of forming or creating new fubftances from them; but the fublime procefs that produces all thefe combinations, the mechanifm by which thefe tranfmutations, modifications, and affimilations are fo conftantly executed, and with fo much harmony, in the organized world, are ftill fecrets which we are not able to penetrate.

Firft Part of a Dictionary of Chemiftry, &c. by J. Ker, F.R.S. & S.A. Birmingham, p. 192. Animalization. 1789. —Effai de Theorie fur l'Animalization et l'Affimilation

des Aliments, par M. Halle, M. D. Annal. de Chimie. tom. 2. p. 158.—Encyclop. Méthod. tom. 2. Chimie. p. 308. Paris, 1792.—Humboldt, &c. Verfuch einer Phyfifchen Darftellung der Lebenskrafte, &c. extracted in the Journal de Phyfique, p. 32. art. Phyfiologie Animale. tom. xlviii. An 7. de la Republique.

DEATH AND PUTREFACTION.

It was the opinion of moſt of the ancients, that nothing periſhed during corruption. Pythagoras aſſerted there was only a change in the modifications of matter, and that real annihilation was impoſſible. Plato relates it as an ancient tradition, that the living ſpring from the dead, and the dead from the living, and that this is the conſtant circle of nature. Hippocrates thought that all animated or living animals, being compoſed of two principles, fire and water, their qualities communicated with each other, affording that infinite variety which appears in all the beings of the world; and that at death nothing periſhes, but the parts only change their form by mixing or ſeparating from each other. Diogenes, Apollonius, and Parmenides ſeem to have held ſimilar opinions. Ariſtotle's ideas were not different, for he ſays, with reſpect to ſubſtances, that the generation of the one is the corruption of the other, and *vice verſa*.

Opinions of the ancients on death.

Hippocrates.

Diogenes and Parmenides.

Ariſtotle.

Among the Roman authors, Lucretius, in his philoſophical poem, called The *Nature* of Things, has beautifully deſcribed theſe ideas of the Greeks.

Lucretius.

"Beſides, as nothing nature's power creates,
So death diſſolves, but not annihilates.
For could the ſubſtances of bodies die,
They preſently would vaniſh from our eye;
Diſſolving, without force, they'd periſh all,
And ſilently into their nothing fall.—
"If all things, over which long years prevail,
Did wholly periſh, and their matter fail,
How could the powers of all-kind Venus breed
A conſtant race of animal to ſucceed?

Or how the earth eternally fupply,
With conftant food, each his neceffity ?—
"But fince the feed's eternal, and the frame
Of bodies, and their union not the fame,
Things may fecure and free from danger ftand,
Until fome envious force fhall break the band,
Thus death diffolves alone, death breaks the chain
And fcatters things to their firft feeds again."

CREECH.

Moderns. Leibnitz.

Leibnitz, among the moderns, has expreffed fimilar ideas. All things are compofed of monads, according to this philofopher, which are fimple, indivifible fubftances; they are the real elements of nature, and as fuch there is no fear of their diffolution. There can be no conception of a fimple fubftance perifhing naturally, but every thing that perifhes, perifhes by diffolution into it's fimple parts, and every thing that is formed, is formed by compofition. Monads, therefore, can only exift or ceafe an inftant, by creation, or annihilation, each monad being in a continued change or viciffitude. Hence it appears, that neither the ancients nor Leibnitz, although they had no idea of the compofition of animal fubftances, ever thought that death was their extinction, but that they again revived under new forms and circumftances.

Signs of death.

Death may be defined the abfence of life, and as it is of great moment to be able to afcertain it with certainty, feveral methods have been proved to enable the phyfician to diftinguifh between it's apparent and real ftate. Behrends and Creve were the firft to prefent to the world galvanifm as the proper teft; the latter in particular has made many experiments to afcertain the fact. This method is remarkable for it's fimplicity and convenience. Upon any anxiety refpecting a fufpicion of a body being not dead, a naked nerve is put into contact with a pair of

metallic rods compoſed of ſilver and zinc, and this will reſolve the important problem, whether any irritability ſtill remains, and conſequently whether the recovery of the corpſe be poſſible. Humboldt, however, although he rejects this as an infallible guide, is of opinion, that it will aſcertain the object to a great degree of probability, and hence recommends it's employment as of great uſe.

The only certain ſign of death is putridity. It's preſence never deceives. When the vital principle, or as Hippocrates calls it, the vital flame, is extinguiſhed in animals, their ſpontaneous decompoſition commences, and this is called the putrid fermentation, or putrefaction. The object of nature in ſubmitting them to this proceſs, appears to be, to reſtore to their primitive elements what life had united, by means of it's different functions, to form a compoſite organized body. The matters, therefore, that formed the bodies of animals, are reduced to their primitive ſimple ſtate, that in proceſs of time, by uniting again with life, through organization, they may be employed in the formation of new complex bodies, whether of the vegetable or animal ſpecies; and this would ſeem to be the ſpeedieſt proceſs by which the ultimate parts of bodies, no longer ſuſceptible of being united to life under one particular form, are tranſlated to another. Thus is nature a ſeries of revolutions, a ſucceſſion of compoſition and decompoſition, of production, and of deſtruction.

Putridity the only certain ſign of it.

There are a number of authors who have written on putrefaction, the principal of which are Beccher, Stahl, Hales, Pringle, Macbride, Geber, Beaumè, and Gardani, ſome of which have deſcribed with great care many of the phenomena that accompany the putrid change in different bodies; but although they have in ſome meaſure cleared this ſubject of the obſcurity it was in before the time of Bacon, many more experiments and obſervations are neceſſary, to give a full and ſatisfactory explanation of

Authors on putrefaction.

the circumftances attending this fpontaneous operation of nature. Their great merit has, perhaps, been to point out the way to others who are defirous of attempting a more minute inveftigation.

Stahl. As upon all other fubjects, there have been various opinions refpecting the nature of putrefaction. Stahl affirmed it to be a real fermentation, and he confidered it as the end or laft ftage which all animal and vegetable fubftances are made to undergo by the fermentative proceffes; and almoft all the later chemifts, fuch as Weigel, Gmelin, Macquer, and Morveau, feem to have been of the fame opinion.

Boerhaave. Boerhaave afferted that it was not a fermentative procefs, but that it was effentially different from it, and he appealed to well known facts in his fupport. Scopoli fided with Boerhaave, forming his decifion from the fame circumftances, viz. that putrefaction difengages volatile alkali, decompofes all the fixed parts of organized bodies, and produces nothing but earth, and fome effluvia, which though moft difagreeable, and even poifons to the human body, yet being imbibed by the earth and vegetable creation, give life to a new race of beings; whilft, on the contrary, during the fermentative procefs, the fibrous texture of fubftances remain undecompofed, and the productions are only fixed air, wine, fpirits of wine, and vinegar. It would appear, however, that Stahl did not look upon putrefaction to be different from the vinous and acetous fermentations, and that they were entirely independent on each other, but only regarded the three as being principal degrees of the fame fermentative motion by which all compofed bodies are diffolved and reduced to the fame ftate; hence, that putrefaction was a kind of fermentation or rather the laft ftage of that procefs, beginning with the vinous, going through the acetous, and ending with the laft ftage of putridity. It

has likewife been alleged, that if it be a fermentation, it muft neceffarily be a diftinct kind, fince we frequently obferve it taking place, where neither of the other ftages had preceded it, which proves that in fome cafes at leaft, it muft be entirely independant of, and unconnected with them. Putrefaction has likewife been regarded as a fpecies of ignition: it is faid that the power it has of converting every thing into earth, is evidently performed by an expanfive power, that in confequence of this, the body firft fwells, then burfts; vapours are extricated and fly off, and the particles fall afunder from each other, which are the very effects the action of fire produces upon any combuftible body; hence it is probable that the agent in the air confidered as the caufe of putrefaction, is no other than the fire itfelf; *i. e.* the ethereal fluid expanding itfelf every where, and that inftead of an emiffion of flame, which ignition is attended with, putrefaction is accompanied with a production of azotic gas.

Subjects of putrefaction.

All organized, and particularly animal fubftances, undergo the putrid fermentation; and Leonhardi is of opinion, that a flight acetous fermentation takes place, previous to it; this may proceed from the gelatin, which under certain circumftances, as in broth, is faid to be fubject to the acetous procefs.

Various kinds of putrefaction.

The putrefaction or fpontaneous decompofition of animal fubftances, may be divided into as many fpecies as there are chemical agents in nature capable of producing it, thus, when it takes place in the open air, it may be called, *atmofpheric* putrefaction. But when in confequence of bodies not being expofed to the external air, a decompofition takes place amongft their component parts, and new combinations arife, the products are totally different. In thefe cafes, the principal effect is their being deprived of their azot; fuch is the cafe when

bodies are heaped together in the earth, and hence it may be called *terraneous* putrefaction; or under water, giving rife to the *aqueous* putrefaction. In all thefe cafes where the air is excluded, a more or lefs oily mafs is produced. The fame took place during the *internal* putrefaction of the human liver, as defcribed by Fourcroy.

1. Atmofpheric putrefaction.

1. *Atmofpheric Putrefaction.* When an animal fubftance is expofed to the atmofpheric air, fo as to give rife to it's fpontaneous decompofition, it paffes with more or lefs rapidity through the following changes, particularly affecting it's colour, fmell, and confiftence. It becomes of a paler colour, it's confiftence is diminifhed; if it be folid as flefh, for inftance, it foftens, and a ferous kind of matter oozes out, it's colour quickly changes, it becomes relaxed in it's texture, and it's organization is deftroyed; it has a faint and difagreeable fmell, it finks down and is diminifhed in bulk, and it's fmell becomes ftronger and alcaline. If the fubftance be contained in a clofe veffel, the progrefs of putrefaction, according to Fourcroy, feems to flacken at this ftage, and no other fmell but that of a pungent alcali is perceived; it effervefces with acids, and changes the blue of violets to a green colour. If, however, the communication of the air be admitted, the urinous exhalation is diffipated, and a peculiar putrid fmell extends itfelf with great impetuofity, and of the moft infupportable kind. This fmell continues a long time, fpreads every where, pervades every place, and affects the healths of living animals fo as to produce putrid difeafes. This fmell Fourcroy obferves, is connected, and as it were confined by the volatile alcali, which when volatilized, is fucceeded by the putrefactive procefs, becoming active a fecond time, the fubftance fuddenly fwells, is filled with bubbles of air, but foon after fubfides again. The colour now changes, the fibrous texture of

the fleſh is ſcarcely to be diſtinguiſhed, and the whole is converted into a ſoft pulpy brown, or greeniſh matter, of the confiſtence of poultice, with a faint, nauſeous, and diſguſting ſmell, that is very active and contagious. This ſmell gradually ſubſides, the fluid portion of the fleſh aſſumes a kind of confiſtence; it becomes of a deeper colour, and the whole is finally reduced to a friable matter, ſomewhat deliqueſcent, which on being rubbed between the fingers, breaks into a coarſe dark powder like earth. This is the laſt ſtate animal ſubſtances undergo during this proceſs, for which a conſiderable time is neceſſary. For the total deſtruction of the whole body of an animal, it is ſaid that eighteen months, two or even three years are ſcarcely ſufficient when expoſed to the external air.

During the time animal matters are undergoing the above changes of decompoſition, their component parts fly off, or form new combinations, either with the vital air of the atmoſphere, or by ſimple attractions between each of their principles, they form unions amongſt themſelves, giving riſe to ſimple, binary, and even ternary combinations. The products are carbonic acid gas, ammonia, nitric acid, ſulphur, phoſphorus, hydrogen gas, and the ſubſtances it diſſolves, azot gas, Pruſſian blue and heat, which being diſengaged by degrees into the atmoſphere, diminiſh in proportion the maſs of animal matters, and there remains an earth behind. Products of it.

1. *Carbonic acid.* This is diſengaged from putrefying bodies, particularly from ſolid parts, in large quantity. The quantity appears to be in the inverſe proportion of the quantity of hydrogen gas extricated, for at firſt it is in large proportion, and the hydrogen gas in ſmall proportion, but afterwards the contrary takes place. The firſt product Lavoiſier obtained from the fecal matter of a neceſſary in a putrid ſtate, was theſe two gaſes mixed Carbonic acid.

together; 11 parts of carbonic acid, and one of azot gas. The temperature was at 8° or 10° of Reaumur. Priestley has likewife afcertained their proportion and quantity. Having let 4 pennywts. 6 grs. of lean mutton become putrid, he obtained 2 $\frac{11}{24}$ oz. meafures of gas, of which 2 $\frac{15}{200}$ were carbonic acid gas, the remainder hydrogen gas. Corvinus long ago obtained a quantity of elaftic fluid, from putrid fubftances, one of which was imbibed by water, the other not, they were therefore very probably the fame gafes.

The carbonic acid has been fuppofed to have already exifted in animal fubftances expofed to putrefaction, and to have been only extricated during that procefs; but Lavoifier found that new fecal matter would not effervefce with acids, whilft an effervefcence took place with it in it's old ftate, which certainly is againft this fuppofition: fome chemifts, and particularly Berthollet have afferted, that it arifes from the decompofition of the water, that the vital air unites with a portion of the carbon of the animal matter, and forms carbonic acid, whilft the other principle of the water, the hydrogen, is fet at liberty in the form of a gas; hence two gafeous fubftances are obtained, the carbonic acid and hydrogen gafes. There is, however, fome doubt of this origin of the carbonic acid; and other chemifts are of opinion the oxygen is fupplied by the atmofphere, fince there is no extrication of carbonic acid, unlefs the fubftances are in contact with the atmofpheric air. It is in large quantity in the beginning of putrefaction, at which time it only exifts. It is the gas that is often fo fatal to people who defcend into vaults, and thofe places where animal fubftances are left to putrefy.

Ammonia. 2. *Ammonia*. It was long fuppofed that ammonia already exifted in animal fubftances before putrefaction commenced, but Berthollet found that when frefh, no

animal matter contained it perfectly formed, and that when deprived of azot, by the nitrous acid, they no longer afforded ammonia by any means, particularly by diſtillation. It has been before obſerved, that animal ſubſtances contained a large portion of azot, and this accounts for the origin of ammonia; the azot combining with the hydrogen of the water, (where oxygen, or at leaſt part of it formed carbonic acid with the carbon,) forms a union, which being let looſe, is the volatile alcali ſo very prevalent amongſt putrid ſubſtances by it's pungent ſmell. It is neceſſary, however, for the formation of this alcali, that the two principles meet and unite at the time they are diſengaged, and juſt taking the gaſeous form; for if both the azot and hydrogen were enveloped in their ſolid combination, no union could take place, which happens in thoſe animal matters that have undergone no alteration; if on the contrary, one of theſe two principles is developed without the other, and ſeparates from the matters that contain it in the form of an elaſtic fluid, the production of this alcali is equally prevented, as is the caſe when the nitric acid is uſed. But by the ſlow and gradual action of putrefaction, or by that of fire increaſed by degrees, as in diſtillation, the intimate union of theſe two principles is accompliſhed, by favouring their ſlow and ſimultaneous evolution, and by carrying them within the reciprocal attraction of each other. It is from the ſame circumſtances perhaps, that Gaber was not able to diſcover any ammonia in putrid ſubſtances, either in the beginning of that ſtate, or towards the end, and which led him to deny the exiſtence of it at theſe periods of putrefaction. Crell likewiſe found it was not to be met with at all periods; he is, however, of opinion, that it's preſence is to be found as long as the putrid ſmell continues, whilſt Porner affirmed it's preſence to be a ſign, that the putrefactive proceſs has arrived at it's greateſt height,

and is approaching to an end. From the facts of the production of ammonia, it appears that nature, by allotting to animal fubftances the property of forming this alcali, has given one of the principal means of their decompofition, and fpontaneous deftruction; for as foon as the azot feparates to unite with the hydrogen, the bond of their intimate compofition is relaxed; this alcalefcence may then be looked upon as a fign of great diffolution and perfect diforganization, which cannot take place in animal matters, without bringing on their total deftruction.

Probability of the formation alfo of potafh and foda.

There is great reafon to believe that, befides this alcali, the two others, viz. potafh and foda, may be produced during putrefaction, although their component parts are at prefent not well afcertained. There is an account by Morveau, in his experiments on the effects of different gafes on flefh, that having fufpended a piece of lean beef in a bottle, filled with nitrous gas, which was covered with a moift piece of bladder, and well tied, he found on opening it five years after, that cryftals of nitre were formed in it; real nitre is likewife found near privies, as particularly inftanced by Dr. Wall. The formation of the nitrous acid may be accounted for from the exiftence of it's radical, but that of the *potafh* is difficult to explain. Thouvenel, who appears to have obferved a fimilar phenomenon, admits an epoch of *alcalefcence* in putrefaction, after that of *acefcence*. The fame author has obferved, that where putrid fubftances are expofed for the formation of faltpetre, the *mineral alcali* is likewife formed.

Nitric acid.

3. *Nitric acid.* It had long been known that the putrid fermentation was very neceffary to the formation of nitre, and Kunckel, Vieuffens, and Homberg had remarked that putrid plood when dried and expofed to the air afforded it in large quantity. Juncker relates

that Kunckel having let ſome blood putrefy, until it was reduced to an earth, lixiviated and evaporated the liquor until a pellicle appeared, and obtained from 100lb. of blood, rather more than 5lb. of cryſtallized nitre. But the moſt direct and ſimple experiment was made by the Commiſſioners of the Academy: they put ſome chalk well lixiviated in boiling water into baſkets, and expoſed them to the vapour of putrid ox blood, at about two feet diſtant from each other; when at the end of a few months, the chalk was found to contain four or five ounces of ſaltpetre for each quintal; from which they conclude, that the nitrous acid is produced by the union of the vital and the putrid airs, provided every thing is tranquil, and the atmoſpheric air is renewed by little at a time, and ſlowly. Thouvenel made ſome experiments on this ſubject, by putting into different veſſels air diſengaged from putrid matters, with various aëriform fluids, and into which he had previouſly put ſome alcali or earth, in order to fix the acid, and he found 1. that at the end of a few months, nitrous acid was only formed in that veſſel in which was vital or atmoſpheric air. 2. That chalk always afforded it when expoſed to the mixture, and other ſoluble earths, and alcalis very rarely. 3. That of all animal matters, blood affords it in greateſt abundance, and during the longeſt time. Since the diſcovery of Berthollet, that azot is ſo abundant in animal ſubſtances, and ſince the compoſition of the nitric acid has been found to contain that principle, as one of it's component parts, ſome light has been thrown on this obſcure ſubject; and the formation of this acid is now accounted for by ſome chemiſts, from the vital air of the atmoſphere uniting with the azot, which is extricated in the form of gas from the putrid matter; whilſt others on the contrary, as Fourcroy, allege, that there is a decompoſition of the water, and that the oxygen is furniſhed

by that fluid. It was affirmed by Shaw, that the production of this acid was only during the laſt ſtage of putrefaction. It has alſo been obſerved, that it is not a quick but a very ſlow putrid decompoſition that produced the greateſt quantity of this acid; that a too great degree of moiſture, or too long continued, was hurtful; and from the experiments of Crell it appears, that a moderate heat, ſuch as ſpring and autumn, with a change every fourteen days, or once a month, of the ſurface of the putrid matter, and a moiſt atmoſphere, were the moſt favourable to it's generation.

Sulphur. 4. *Sulphur.* According to De la Metherie, this ſubſtance has been found in ſeveral places where putridity is going on, as on the ſides of ſtalls; and according to Rochefoucault, it was found cryſtallized on the walls of ſome old paſſages at Paris, ariſing from the effluvia of putrefying ſubſtances; it has likewiſe been obſerved in the dung of horſes, and is ſuppoſed to be the produce of an incipient putrefaction.

Phoſphorus. 5. *Phoſphorus.* The phoſphoreſcent light obſerved in putrid ſubſtances, and particularly in putrid fiſh, was ſuppoſed by Lavoiſier to be occaſioned by the extrication of phoſphoriſed hydrogen; but Davy accounts for it in a different way. He aſſerts, this luminous appearance ariſes from the liberation of nitric phoſacid, previouſly formed during life, by the combination of light with oxygen and nitrogen. He found by experiment that putrefying fiſh are equally luminous in water, when boiled to expel the air and phoſoxygen.

Hydrogen gas. 6. *Hydrogen gas.* This is another production of putrefaction. It was aſcertained by Lavoiſier from ſome experiments made on the fecal matter of a neceſſary, that the proportion of this gas increaſes with the progreſs of putrefaction, and he continued to obtain it for ſeveral years after the fixed air had ceaſed to be produced, al-

though Prieftley affirms the contrary. Lavoifier expofed four inches of fecal matter to 24 inches of vital air under mercury, and in ten days there only remained $22\frac{1}{3}$ of the air. This diminution of vital air, by it's expofure to new fecal matter, he attributes to the effect of a fmall quantity of inflammable air difengaged; for Prieftley has obferved, that when inflammable air is difengaged flowly from fermentefcible fubftances into vital air, there is an infenfible union between thefe two airs at the moment of the formation of inflammable air; and a further proof of it's being this air which acts on the vital air at this moment is, that if inftead of new fecal matter, which affords very little inflammable air, old fecal matter, or that which is a little advanced in putrefaction, be ufed, it's action on the vital air is greater and more rapid, and a much greater diminution takes place; at the fame time the inflammable air, which would have been obtained by the operation in veffels void of vital air, difappears: hence it is probable that it effects by flow means what takes place immediately in cafe of combuftion. (Vide carbonic acid.)

Hydrogen gas has a very difgufting fmell, and it is found to be capable of diffolving fulphur, phofphorus, and even carbon, which fubftance it depofits again on the addition of feveral chemical agents after the folution has taken place. It is therefore afferted by feveral chemifts, that the difagreeable naufeating and even infupportable ftench which arifes from fubftances in a putrid ftate is owing to hydrogen gas; either in it's free ftate, or holding in folution fulphur, in which ftate it is called fulphurous hydrogenous gas; or phofphorus, when it is called phofphorated hydrogenous gas; or carbon, forming carbonated hydrogenous gas. The difference or degree of fmell may likewife be attributed to the difference or degree of folution. If the hydrogenous gas be alone, it is perhaps the

leaſt unpleaſant; combined with ſulphur, it has the ſmell of rotten eggs; and with phoſphorus, that horrid ſtench is produced peculiar to ſtinking fiſh. The carbonated hydrogenous gas no doubt likewiſe produces it's peculiar ſmell, but as theſe odours are generally mixed during putrefaction, they are perhaps only to be diſtinguiſhed at particular ſtages of it, when the one or the other predominates.

Azot gas.

7. *Azot gas.* This is obtained from putrefying animal ſubſtances either in it's combined ſtate, or united with hydrogen forming ammonia, or with oxygen forming the nitrous acid; it may likewiſe form other combinations. According to Fourcroy, this gas has a very peculiar and diſtinct odour reſembling fiſh juſt beginning to putrefy; it ſeparates a little carbon from animal ſubſtances, and it gives the greeniſh colour to parts, more particularly to the muſcles, which is ſeen during their putrid ſtate: this chemiſt aſſerts it has a very deleterious effect on living animals, and Dr. Mitchel of New York, as well as Drs. Hamilton and Currie, are of opiuion, that the gaſeous oxyd of nitrogen may have the principal ſhare in generating contagious diſeaſes.

Pruſſian blue.

8. *Pruſſian blue.* Fourcroy has found Pruſſian blue in animal ſubſtances during putrefaction, and a ſmell of pruſſic acid has alſo been obſerved; but as all animal ſubſtances contain the principles of theſe two matters, which require only an opportunity for a union, their preſence in ſome caſes is not ſurpriſing.

Heat.

9. *Heat.* Whether this be a ſubſtance or a ſenſation produced by the repulſive motion of the putrid proceſs, it is found to take place in all matters undergoing that operation, more particularly when in large quantities; this is more evident in dunghills; and we are informed by Munro, that upon thruſting his hand into the fleſh of a dead and corrupting whale, he felt a very ſenſible heat.

10. *Earth.* When the volatile parts, or thofe capable of becoming fo, fly off or form combinations, and efcape in the order of their volatility, and the various odours they give rife to have vanifhed along with them, the putrefactive procefs is over, nature has performed her purpofe, her decompofition is complete, and there remains nothing but an infipid, blackifh, and carbonaceous fubftance, which is called the earth, a fpecies of caput mortuum, which has not been thoroughly examined. It is faid to confift of the oily matter, of calcareous phofphat, and the phofphat of foda, united to a portion of the carbonaceous principle. Earth.

From obferving the phenomena attending putrefaction Boiffeau has diftinguifhed four ftages. The firft he calls a tendency to putrefaction, which confifts of only a very inconfiderable change, perceptible by a flight faint fmell, and a foftening of the fubftance. The fecond degree he calls the commencement of putrefaction, this is fometimes indicated by marks of acidity, the fubftances lofe fomewhat of their weight, become foft and emit a fetid fmell; a ferous matter exudes from them if in clofe veffels, or they become dry or dark coloured if expofed to the air, although if the laft be moift there is little difference. The third degree he calls the advanced ftage of putrefaction, the fubftance emits a volatile alkaline fmell, mixed with a naufeous or putrid aroma, it diminifhes and falls into diffolution, the colour changes more and more, and it lofes both in weight and bulk. The fourth degree, or complete putrefaction is known to have taken place by the volatile alkali being entirely and completely diffipated, the fetid fmell lofes it's force, the volume and weight of the fubftance are confiderably diminifhed, a gelatinous mucus is feparated, the mafs becomes by degrees dry, and is at length reduced to a friable and earthy matter. Four ftages of putrefaction.

Such are the general ſtages and effects which nature produces.

Difference of phenomena.

Theſe phenomena are not however the ſame in all matters that undergo putrefaction. There is a great difference between the putrefaction of the parts of living animals and that of dead organs. Beſides, every humour and every ſolid part ſeparated from a dead animal has likewiſe it's peculiar manner of putrefying. The muſcular, the membranous, or the parenchymatous texture of the organs; the oily, gelatinous, or albuminous nature of the humours, their conſiſtence, their ſtate with reſpect to that of the animal which afforded them, all have a more or leſs great influence on the putrefactive proceſs, ~~and~~ modifying it in a variety of ways, perhaps impoſſible to be eſtimated. If to theſe be added, the ſtate of the air, it's temperature, elaſticity, weight, dryneſs and moiſture, with many other circumſtances, the actions of which are more or leſs to be conſidered, the phenomena will be ſtill more diverſified. Hence we may ſay with Fourcroy, that the hiſtory of animal putrefaction is ſcarcely begun, and demands an immenſe ſeries of experiments and obſervations.

Cauſes aſſigned by different authors.

Several cauſes have been attributed to the production of putrefaction. It was the opinion of ſome philoſophers it was brought about by animalcula and inſects; amongſt theſe were Linnæus, Kircher, and Plenciz; this hypotheſis, however, was overturned by the experiments of Alexander. According to the opinion of Macbride, fixed air is the fundamental cauſe of putrefaction; for as he ſuppoſes this to be the power of coheſion in bodies by which their parts were kept together, it follows, that when this is extricated, as is the caſe in all putrefaction, the other component parts muſt likewiſe ſuffer a decompoſition, the equilibrium between them being deſtroyed.

Another opinion was, that phlogiſton is the cauſe of it, and as it was the faſhion to attribute almoſt every chemical phenomenon to the abſence or preſence of this principle, it was confidently aſſerted, that the decompoſition of bodies is brought about by this phlogiſtic matter being extricated from them, or in other words, that the abſence of phlogiſton was the production of putridity. The phlogiſticarians, and particularly Ker, explain it in the following manner: they look upon the ſeparation of phlogiſton from the other component parts of bodies to be the foundation of this proceſs. When therefore putrefying ſubſtances are expoſed according to circumſtances that favour it, it begins firſt by an expulſion of fixed air, by which much of the pure air of the organic matter is extricated to unite with the phlogiſton for it's formation; another part of the phlogiſton unites with the water, and, the volatility of both being aſſiſted by the heat of putrefaction, riſes in the form of inflammable gas; another portion of phlogiſton evolved and freed from it's organic compoſition unites with a portion of air, forming phlogiſticated air; ſome of this phlogiſton uniting with a great deal of water, ſome earth, and leſs air, forms volatile alkali; the remaining phlogiſton attracting ſlowly the pure air from the atmoſphere, forms, with water and the fixed alkali or the pure earth of the organiſed ſubſtance, a ſaline or calcareous nitre; whilſt the greateſt part of the earth thus ſeparated from it's former combinations remains in it's proper form, or rather in a ſomewhat phlogiſticated ſtate. It was then alleged, that the atmoſpheric air was the grand cauſe; but according to Weber, this air is not only without effect, unleſs aſſiſted by warmth and moiſture, but from the experiments of Alexander, it's free admittance is not indiſpenſibly neceſſary to putrefaction. Fourcroy, and the French chemiſts attribute it to the decompoſition of water; it is their opi-

nion this fluid is decompofed, that one of it's component parts, the oxygen, feizes the azot of the animal fubftance, and contributes to the formation of the nitrous acid, and that the other component part, the hydrogen, uniting with a portion of the fame azot which abounds, produces the volatile alkali. The great difficulty, however, refpecting the decompofition of the water is, that it is unknown how it can take place at fo low a temperature; and to fhow that oxygen is always imbibed by putrefying fubftances, it is only neceffary to examine the air, which is found to be diminifhed, and the oxygen to have difappeared, whilft the prefence of the atmofpheric air is always neceffary for putrefaction to take place, and the purer the air, or the larger quantity of oxygen it contains, the fooner and the more rapid is the putrefying procefs; thefe are great proofs that this principle acts at leaft a principal part in it's production; but as before obferved, it is not the caufe of it.

Morveau, in order to find what action different forts of airs would have upon animal fubftances, filled feven large bottles, and fufpended in each an ounce of lean beef, he then covered the bottle with a piece of bladder, and tied it, leaving them for five years without being opened, when he found, that

	Grains.
In the vital air, the flefh was reduced to	136
Common air	149
Fixed air	157
Inflammable air	163
Nitrous gas	155
Ammoniacal gas	242
Putrid gas	168

In the vital air, this chemift informs us, the putrid odour was perceived the longeft time through the bladder, it was very ftrong after two months, whilft if that

in the common air be excepted, scarcely any thing was emitted from the others; hence it appears, that the vital and common airs had a great advantage over the others, which agrees with the nature of them determined by other properties. All the pieces of flesh were found to be dry and tending more or less to a black colour, especially that in the vital air, which shows that it had made in that air the greatest progress in putrefaction.

The cause or origin of putrefaction is the resumption of the chemical elective attractions which the component remote parts of bodies had been deprived of by the principle of life, and the consequent formation of new combinations brought about by several accessories, or as they may be called, septics, viz. *moisture, moderate temperature, repose, and a communication with the external air.*

A certain degree of moisture appears necessary to give the component parts the liberty of coming within each other's attraction so as to form new unions with the oxygen of the atmosphere, and also amongst each other; whereas dryness prevents, or rather retards it, as well as too much aqueous fluid; hence the preference of a moist atmosphere. Accessories or septics.

2. A moderate temperature, such as 65°, is found to be the heat of the atmosphere most favourable to putrefaction. On the contrary, a great degree is apt to volatilize the parts of bodies before they can form a union, and to produce exsiccation; and a low degree, as that near the freezing point, retards it by not giving the parts sufficient activity to form new combinations, whilst congelation stops it altogether.

3. Repose is likewise a great assistant in this process, for without it there is no time for new unions to take place, and a quick succession of air takes away the moisture so necessary, and dries the external parts; a confined air is the greatest promoter of putrefaction.

4. Bodies will not putrefy in vacuo, hence the atmofpheric air is equally neceffary with the others, and it is always found to be diminifhed, as is the cafe whenever it's oxygen is abforbed, *i. e.* in all proceffes which the old chemifts called phlogiftic; and the larger the proportion of oxygen the quicker and more perfect is the putrefaction. It is on this account that great fimilarity has been obferved, particularly by Goddard, between the putrefactive procefs and the action of fire on the atmofphere during combuftion, both converting fubftances into an earth, and caufing an abforption of the oxygen of the atmofphere, and a generation of fixed air; but as the putrefactive procefs is much flower than either moift or dry diftillation, the products are different in fome refpects, from the great degree of heat not permitting the component parts to form the fame unions. They both decompofe animal fubftances and form new compounds. Both in diftillation and putrefaction, fixed air, ammonia, hydrogen gas, and fulphureous hydrogen gas are obtained; but in the firft, the heat being very powerful, forces more or lefs carbon from it's combination, which uniting with hydrogen forms an oil more or lefs empyreumatic, according to the quantity of carbon; whilft in the fecond, when there is fufficient repofe and time for the azot to unite with the oxygen of the atmofphere, the nitric acid is produced.

Diftillation compared to putrefaction.

Thefe four acceffories being the grand promoters of putrefaction without which it cannot take place, it follows, that fubftances which are favourable to thefe promote putrefaction; and on the contrary, thofe which impede them, more or lefs prevent it. It is principally on thefe grounds that experiments have been made to find what fubftances promote, and what retard or prevent it; the firft have been called feptics, the other antifeptics. For many experiments of this kind we are indebted to Prin-

gle, Macbride, Buckholz, Brugnatelli, Spielman, Morveau, &c., but great additions are neceſſary to determine the relative powers of ſeptic or antiſeptic bodies with any degree of preciſion.

Antiſeptics.

Pringle and Macbride were the firſt to make experiments to prove what thoſe ſubſtances were that oppoſed putrefaction. In taking the general concluſions not only of the experiments of theſe two phyſicians, but of thoſe of Buckholz, Brugnatelli, and Morveau, it appears, that ſubſtances which are antiſeptic are not only incapable of putrefaction themſelves, but they deprive thoſe which promote it of their energy, at leaſt in a greater or leſs degree; among theſe are dry earths, acids, alkalis, neutral ſalts, ſpirituous liquors, eſſential and empyreumatic oils, balſams, reſins, ſpices, bitters, aſtringents, ſmoke of different kinds, and all gaſes or airs, except thoſe into which oxygen enters as a conſtituent part, as the atmoſpheric air.

All theſe impede the putrefactive proceſs, at leaſt, animal ſubſtances are longer in becoming putrid in them than when expoſed to the atmoſpheric air, &c. It is likewiſe found, that the fermentation of vegetable ſubſtances is increaſed by a mixture of animal matter, and the putreſcency of the latter is corrected by the oppoſite quality of the former.

Preparation of animals.

By making uſe of thoſe means, which prevent putrefaction, and by the aſſiſtance of thoſe ſubſtances that are called antiſeptics, the bodies of animals or their parts may be preſerved for a great length of time. This has been practiſed from the earlieſt ages, by the name of embalming. According to Diodorus Siculus, the ancient Egyptians were accuſtomed not only to embalm the dead bodies of thoſe animals their ſuperſtition had rendered holy, but likewiſe human bodies which were thus preſerved from a ſpontaneous decompoſition, and are ſo abundantly

Art of embalming by the Egyptians.

to be found by the name of mummies. We are informed by Herodotus, as well as the before-mentioned author, that the Egyptians had ſeveral methods of embalming the human body, three of which are particularly noticed. To this difference in the proceſs, Leonhardi attributes the different opinions phyſicians and chemiſts have had of this ancient operation.

Three methods.

1. A hole was made through the noſtrils into the cranium, the brain extracted, and the cranium was filled with the embalming ſubſtance. The thorax and abdomen were then deprived of their viſcera, except the heart and kidneys; they were waſhed with Phœnician wine, and filled with ſweet-ſcented reſins and aromatics; the opened parts having been afterward ſewed up, the body was well waſhed and cleanſed, and placed in natron, which is ſuppoſed to have been the mineral alkali united with common ſalt, and found native in Egypt. In this alkali it remained about 30 days; it was taken out and waſhed a ſecond time, beſmeared over with a gum or reſin, carefully enveloped with cotton bandages and placed in a coffin. This method was very expenſive, but is the only one that merits the name of embalming.

2. A cheaper way of preſerving the body was to introduce various reſins, particularly that from the cedar, by the anus, without opening either the belly or thorax, the body was then dried in natron, and afterwards the reſin with the corroded inteſtines were taken away.

3. The cheapeſt method conſiſted merely in waſhing the body, and it's expoſure to the action of natron, which we are informed deſtroyed the fleſh and only left the ſkin and bones.

Opinions on the ſubſtances employed.

With reſpect to the embalming ſubſtance employed on theſe occaſions there are various opinions. Some, as Rouelle and Vandermonde, look upon it to have been aſphaltum mixed with the oil of the cedar ſeed; whilſt

Hardley thinks, with the ancients, it was the resin of this tree, or some other vegetable resin. Belloni and Blumenbach are of opinion that asphaltum was used in common operations as being the cheapest, and that, on particular occasions, the odoriferous vegetable resins were chosen; and the latter chemist, on the examination of ten different mummies, found no asphaltum, but very evident traces of vegetable resins. It is, however, certain that the substances for this purpose were not always of the same kind.

Attempted by the moderns.

The art of embalming the human body has likewise been attempted by some of the moderns, but the mere action of saline bodies, and filling the cavities of the body with aromatic herbs, were found not to be sufficient to preserve it from putrefaction. The best and perhaps the only method worth attention is that pointed out by Dr. Hunter. As soon as the corpse is become cold and stiff, and before any symptoms of putrefaction appear, it is to be well washed with warm water; one of the large arteries is then to be laid open, and the following injection to be forcibly made to enter the smallest vessels, even those of the cellular membrane. Two parts of the oil of chamomile are to be mixed with eight parts of oil of lavender, and sixteen of oil of rosemary; likewise the oil of turpentine may be either used alone or mixed with a little of the oils of rosemary and lavender; or, to give it a colour, a little cinnabar may be united with the oil of turpentine. The different viscera are in a short time after to be extracted, the intestines to be carefully cleansed of their contents, and the rest of the viscera to be deprived of their moisture by wiping them repeatedly with dry towels; the body is likewise internally to be cleansed of it's blood and injected oils, by squeezing the vessels; the arteries are then to be injected as well as the other large vessels that have been cut, with a mixture com-

Dr. Hunter's.

pofed of 6 lb. of oil of turpentine, 5 oz. of turpentine, 11 oz. of cinnabar, 2 oz. of camphor, and 3 lb. of ftrong fpirit of wine; with this likewife the flefhy parts that have been well deprived of any moifture are to be carefully anointed, the veffels of the inteftines to be injected, and then to be replaced in their former fituation, fcattering a fufficient quantity of a powder about them, compofed of 10 lb. of yellow refin or pitch, 6 lb. of faltpetre, and 5 oz. of pulverized camphor, fo that every vacancy may be perfectly replete with it. Afterward, when a little of the injecting liquor above mentioned has been poured into the thorax and belly, the fkin is to be clofed, the mouth, pharynx, and larynx fyringed and filled with the powder, together with the cavities of the ears, nofe, anus, parts of generation, eyes and eyelids, and the whole body, after having been previoufly wafhed and rubbed dry, is to be well rubbed with alcohol and camphor, and finally with the oils of rofemary and lavender. The body being thus embalmed, in order to deprive it of any remaining moifture, it is to be laid in a coffin upon fome calcined and finely pulverized gypfum, fo as to be on all fides about half covered with it; pieces of camphor are to be ftrewed about, and a range of open bottles filled with volatile oils; the coffin is then to be well clofed, having a lid with a glafs in it. In about four years the gypfum fhould be renewed, and when the body is perfectly dry, it may be difpenfed with altogether.

Preparation of animals by naturalifts.

Befides the embalming of the human body, chemiftry is able to afford great affiftance to the naturalift in the preparation of quadrupeds, birds, and other animals that compofe collections of natural hiftory. It affords the moft proper means not only of being able to give them duration and confiftence, but to make them deviate as little as poffible from the living ftate, that by their attitudes and moft natural pofitions, they may be enabled to

exhibit in great perfection both their inftinct and character, circumftances of great importance in the fcience of natural hiftory.

For thefe effects, the methods publifhed by Reaumur in the 45th vol. of the Philofoph. Trans., and thofe related in the Dict. d'Hiftoire Naturelle, when chemically examined, are far from being fatisfactory. Independent of the method of embalming propofed by Dr. Hunter juft mentioned, which may be applied alfo to fubjects deftined for natural collections, feveral chemifts have given directions for that preparation; amongft the principal of which are Kuckham, Chaptal, and Pinel.

Kuckham publifhed a procefs for the preparation of birds in the 60th vol. of the Philofoph Trans. His compofition to preferve them from putrefaction is a mixture compofed of a quarter a pound of corros. fub.; half a pound of calcined faltpetre; a quarter of a pound of calcined alum; half a pound of flowers of fulphur; a quarter of a pound of mufk; one pound of black pepper, and one pound of pulverized tobacco; thefe are to be kept in a well-clofed glafs veffel, and in a dry place. The corrofive fublimate is very fatal to infects; and, according to Pinel, the only objection to the mixture is the expenfe. He therefore fubftitutes the following in it's place; equal parts of corros. fubl. or arfenic, calcined alum, camphor, canella, or any other aromatic, are to be pulverized and mixed together. Pinel has likewife made ufe of a varnifh with great fuccefs; it was, he informs us, at firft kept a fecret, and is a very fure means to prevent the generation of infects in the fkins of dead animals, or to deftroy them when hatched; fo that for three or four years, until they can be conveniently placed in the collection they are deftined for, the keeping them under cafes of glafs may be difpenfed with. It is compofed of the following articles: Four ounces of pulverized arfenic are to be put into one pound of brandy,

Method of Kuckham.

Pinel.

the mixture heated gently, fome black foap and aloes are then to be added, fo as to form a kind of magma, which muft be lightly extended whilft warm in the interior of the animal with a brufh, the foft parts having been taken away; the fame procefs muft be applied to the internal furface of the fkin. When ufed, he recommends it to be diluted with alcohol. Immediately after it's ufe, the preparation fhould be *mounted*, as the evaporation of the fluid part occafions the fkin to become hard and difficult to foften again.

It is with this magma that cotton or flax ought to be impregnated, with which the internal parts of animal bodies are to be filled, and it is found to be far fuperior to the mixture compofed of a folution of camphor in rectified fpirit of wine, which is commonly ufed in this country. It is likewife neceffary that the zoologift fhould be provided with cauftic foda, a folution of which corrodes the foft parts, and by uniting with the fat parts forms a fpecies of foap that is afterwards eafily taken out by repeated lotions Chaptal recommends the cranium and inteftines, when deprived of their contents, to be fyringed with vitriolic ether.

Chaptal.

Small animals, or the parts of large ones, are ufually preferved by being kept in fpirit of wine; for this purpofe, it is obferved by Leonhardi, that a little water and a fifth part of fpirit of fal ammoniac fhould be added, which will preferve the colour and foftnefs.

A method of preferving anatomical fubjects in a very perfect manner, is the following. It is faid to have been made ufe of by John Sheldon. He injects feveral parts of the body with ftrong fpirit of wine, faturated with camphor, and mixed with a fmall portion of turpentine. The fkin is prepared with finely pulverized alum, rubbed on with the hand. The inteftines are taken out and covered with a varnifh, compofed of a mixture of camphor, and

Sheldon.

common refin. All the internal parts of the body undergo the fame operation, and are afterwards rubbed with alum. The body thus prepared is laid on a bed of calcined chalk to the thicknefs of one inch, in order to abforb all humidity, and is then placed in a double cafe of wood, the inner of which is of cedar. In this manner he has been able to preferve the body of a young woman for feveral years, which retains it's form and appearance nearly as perfect as in life. Even the natural tint of the fkin of the face is preferved, by a coloured injection impelled through the carotids to produce that effect.

Chauffier has difcovered, that if the bodies of men or other animals be plunged for fome time in a folution of corrofive fublimate, and then dried, they affume the confiftency of wood, and the air produces no effect upon them afterward; and if the bodies be injected previoufly, they will retain the colour and appearances of life, and confequently form mummies more perfect than the Ægyptian. Chauffier.

It is well known, how difagreeable and very inconvenient that putridity is to the anatomift, which often fo foon takes place in bodies or their parts under diffection, and to Fourcroy it is, that we are indebted for a method by which thefe inconveniences may be prevented: it confifts in fprinkling the parts with oxygenated muriatic acid. He informs us, the abdominal mufcles of a fubject for demonftration having been removed, and the cavity of the abdomen laid open, notwithftanding the contents were carefully removed, it was found to exhale a confiderable putrefactive fmell; care, however, being taken to wafh the whole internal furface with the liquid oxygenated muriatic acid, the odour was immediately deftroyed, and the ftudents that had quitted the body foon refumed their fituation without being afterwards incommoded; they alfo continued their diffection in the abdominal Fourcroy.

cavity, and in the cheft, which was alfo wafhed with the fame, for a much longer time than ufual without perceiving any degree of fetor. A mild and humid ftate of the air, during which the putrefaction of bodies is known to proceed very rapidly, produced little effect for the fpace of eight days, on the body fprinkled by the acid, whilft in the fame period other bodies had acquired the higheft degree of putrefaction. The mufcles, the nerves, the vafcular membranes, and all the other parts continued firm and without alteration.

This chemift therefore advifes, that in bodies for diffection, the parts fhould be fprinkled as they are laid open. This method, which will preferve bodies for more than fix weeks, taking care to repeat it from time to time, is eafily practifed, as a fponge dipped in the acid is flightly rubbed over the parts, taking care to avoid the vapour by turning the head afide.

He likewife advifes the ufe of this acid for another purpofe during diffection. One of the great difficulties in diffecting the foft and pulpy parts, as the brain, cerebellum, medulla oblongata, and fpinal marrow, is the want of firmnefs in their ftructure, and the confequent yielding of their particles to any impreffion. This foftnefs likewife renders them very liable to change by putrid decompofition, and they become oftentimes fo putrid in a few hours, as to make it impoffible to determine their ftructure, although thefe parts, to be well underftood, require a long and attentive examination. It has been propofed to heat them a little above 45° of Reaumur, to give them a firmer confiftence, and although the albuminous matter which forms their bafis is fufceptible of this denfity from the impreffion of heat, it is not fufficient for the anatomift, as the foft fibres of thefe organs are compreffed together, and become lefs apparent after the operation. Fourcroy, therefore, thinks he has dif-

covered a more advantageous method. Having obſerved that all animal ſubſtances, eſpecially the ſkin, membranes, &c. become firm and compact after maceration for ſome hours in liquid oxygenated muriatic acid, and that their fibres were made to approach each other in a remarkable manner; he ſteeped a human brain for eight hours in this liquid, and afterward plunged it once or twice in freſh water to waſh off the acid, and found it's ſubſtance became firm, was readily cut, and it's tiſſue not diſorganized by gentle preſſure, as is generally the caſe with this organ. It alſo preſerved it's whiteneſs and conſiſtence for more than eight days, and did not become putrid in near the ſame time as in ordinary circumſtances.

The utility of this property of the acid, in hardening and preſerving animal ſubſtances, is likewiſe extended to the ſoft and almoſt mucous fleſh of moſt fiſhes, and the glairy ſubſtance of worms, ſnails, &c., which is of great importance in the art of anatomy.

Having deſcribed the phenomena, and the circumſtances attending *atmoſpheric* putrefaction, and the methods of preſerving animal ſubſtances from it, an account of the decompoſition they undergo, on expoſure to other mediums, may be a means of throwing ſome light on the revolution the animal creation goes through in it's various metamorphoſes.

2. *Terraneous putrefaction.*

The phenomena which take place when bodies are buried in the ground are different from thoſe which follow on expoſure to the air. It appears their deſtruction varies according to the nature of the ſoil. Sometimes bodies are found to have undergone a total decompoſition after a very ſhort interval, and at other times, as is the caſe with mummies, centuries are neceſſary entirely to deſtroy them. It is eaſy to conceive, according to Four- 2. Terraneous putrefaction.

croy, that if the earth be very porous and movable, if the animal matter be buried at a fmall depth, the air, and efpecially the water, which can have no difficult accefs to it, will facilitate it's decompofition, whilft in oppofite circumftances it muft be much flower; thus, for example, if the earth be dry, it will abforb the aqueous part of the bodies, exficcate and convert them into mummies, as is the cafe in Egypt, where a fandy foil expofed to a burning fun gives them a hardnefs that defends them from deftruction for ages. On the contrary, if the bodies be buried in argillaceous earth, which retains the water, the deftruction is accelerated. In thofe cafes where the decompofition takes place more or lefs flowly, the fluids and the folids become at laft reduced almoft to azot, carbonic acid, hydrogen, and alkaline gafes. All thefe elaftic fluids being filtered through the earth, efcape and experience other viciffitudes; but as the fpontaneous decompofition of animal matters, efpecially when buried in large maffes in the earth, affords fome curious and fingular refults, it will be neceffary to give a more detailed account of them, fuch as they have been collected by Fourcroy, in a memoir written on the bodies found in the churchyard of the Innocents at Paris.

Bodies in the Innocents at Paris.

It appears that the earth of this churchyard had been furcharged for many ages with bodies delivered up to putrefaction in large maffes, which in confequence might be fuppofed to have a different effect from that of other cemeteries, where each body has it's peculiar lot of ground, and where nature is able to feparate it's elements with facility and promptitude. The calculations of fome philofophers had indeed extended the total deftruction of a body to about fix years, from the obfervations made upon common burying places; but thefe could not be applicable to the cemetery of a large city like Paris, in which many fucceffive generations of it's inhabitants had

been buried for more than three ages; for nothing indicated that the entire decompofition of a body might be prolonged beyond forty years, nor could it be fuſpected what a fingular difference nature was able to prefent in the deſtruction of bodies buried in large quantity, and of thofe only ifolated in the earth; nor could it be known what might be the effects of an earth many yards deep, the ſtratum of which was inceſſantly expofed to putrid emanations, and faturated with animal effluvia, upon new bodie placed in it; thefe, however, have been difcovered by Fourcroy, forming an important addition to the hiſtory of animal decompofition or putrefaction.

The remains of the bodies buried in this churchyard were found in three different ſtates, which appeared to depend on the time they had been inhumed, the places they occupied, and their difpofition relatively to each other. Found in three different ſtates.

1. The oldeſt only offered to obfervation a few portions of fcattered bones placed irregularly in the foil from having been often diſturbed to give place to others, and in which nothing appeared except their difference from other human bones that had not been in the earth, and it was with refpect to the foft parts including the teguments that the two following differences were obfervable.

2. Of the ifolated bodies, the ſkin, mufcles, tendons, and the aponeurofis, were dried, brittle, hard, of a more or lefs gray colour, and refembled the mummies in the catacombs at Rome, or in the cellar of the Cordeliers at Touloufe.

3. The third, and moſt curious ſtate, was found to exiſt in the foft parts of the bodies that were accumulated in the common pits. Thefe pits were above thirty feet in depth, twenty broad, and of the fame width; they were dug in the cemetery for the reception of the bodies of the poor, which were placed in clofe ranks, in coffins,

fo that the whole pit was a mafs of bodies feparated only by the thin fides of the coffin, and each pit contained from 1000 to 1500 bodies. Three years were neceffary to fill one of them, and they were opened again to receive other bodies not fooner than fifteen years, nor later than thirty years. The gravediggers had, however, been taught by experience, that this period was infufficient for the total decompofition of the body, whilft the alteration it underwent during the time was well known to them. This change likewife ftruck the obfervation of Fourcroy, in the very firft pit he was prefent at when opened. It had been filled and clofed about fifteen years. The fides of the coffins were found, and tinged of a yellow colour. On taking off the lids, the bodies appeared flat as if they had been preffed, and when the fhrowd was removed, the matter that furrounded the bones was in irregular maffes of a foft ductile confiftence, and grayifh colour. On preffing this matter with the finger, it gave way and broke. It refembled in appearance common white cheefe, and the print of the linen left upon it's furface heightened the refemblance. On rubbing this fubftance, it became foft. The gravediggers were accuftomed to call it *fat*, from it's great fimilarity to that fubftance, but they only found it in bodies buried in mafs, and never in the ifolated ones. There was no infectious or very difagreeable odour perceived. This chemift examined many bodies of this kind, but all were not equally far advanced in this fingular converfion, fome of them had ftill portions of mufcles remaining amongft thefe white fat maffes, which were recognized by their more or lefs red colour and fibrous texture. In the bodies totally converted, there was no veftige of either fkin, membrane, mufcle, tendon, veffel, or nerve; the grayifh white mafs that covered all the bones appearing like cellular membrane, which, according to this chemift, might

Their curious converfion into a fat matter.

induce an opinion of the mucous part being the real bafis of this fingular matter. On examining further, it was found that all the vifcera were likewife fo changed as to leave fcarcely any trace of them; the abdominal cavity no longer exifted, and it was in vain to feek in the greater number of bodies either for the fituation or fubftance of the ftomach, inteftines, bladder, liver, kidneys, or womb; all were, to ufe the expreffion, melted down into this fatty matter. It was the fame with the cavity of the thorax, it no longer exifted. It's vifcera were often entirely changed, and the greater part had difapppeared, nothing remaining but fome lumps of this white fat. He found this matter, which is the product of the decompofition of the vifcera charged with blood and different humours, to differ from that on the external part of the body and bones, by being always of a more or lefs red or brown colour, and that the fat parts afford a much greater quantity than the others.

The face, in general, was no longer to be recognized; the mouth was diforganized, and without tongue or palate; the cartilages even of the nofe partook likewife of the general alteration; the orbits, the ears, were equally changed. The fkin, however, retained the hair, which appears to fubfift the longeft, and make the greateft refiftence to every change, whilft the brain was always prefent, but converted like the other organs.

With refpect to the modifications of this fubftance, it's confiftence was not always the fame; in bodies the lateft changed, *i. e* from three to five years, it was foft and very ductile, very light, and contained a large portion of water; in thofe which had been changed from thirty to forty years, it was more dry and brittle, it's foliated texture was much denfer; and in fome bodies where the foil was dry, portions of it were become femi-

tranfparent, and it's afpect, texture, and brittlenefs, very well imitated wax.

The epoch of it's formation has likewife a great influence on the nature of this fubftance; all that had been formed a long time was in general white, homogeneous, without any appearance of fibrous or foreign matter, and this was more particularly the cafe with the fkin of the extremities. On the contrary, in bodies recently converted, it was not fo pure; there were fome portions of the mufcular, tendinous, or ligamentous parts, the texture of which, though they were altered in colour, was ftill to be recognized; but thefe were more or lefs penetrated with fat matter, to be feen between the interftices of the fibres. Hence not only the fat parts, but the other parts are really converted into the fame fubftance, although the firft undergo the change much more eafily and quickly.

Two varieties of it.

From the obfervations of Fourcroy, it appears, therefore, that amongft the modifications refpecting the ftate of bodies converted into fat, two varieties may be diftinguifhed; the one dry, friable, and brittle; the other foft, and ductile; to which may be added, that the firft, which is oftener found in bodies placed near the furface, not only differed from the other by the water it had loft, but it had undergone a new change, and it had loft one of it's principles by volatility, fo as no longer to be of the fame nature as the other, as will appear.

This fat matter, in fome of the bodies, was very beautiful, it's furface brilliant, and of the colour of gold and filver, and appeared covered over with a flight ftratum of mica, whilft fome points were of a red, orange, and carnation colour, and of extreme brilliancy, more particularly near the bones, which were themfelves penetrated with it.

From the account of the fexton, it feems nearly three years are neceffary for a body to become changed in the earth, and the fucceffive alterations they undergo before they arrive at the ftate already mentioned, are the following: the inhumed bodies appear not to be fenfibly changed in colour before feven or eight days, and this alteration firft takes place in the lower belly, as is the cafe with thofe bodies not inhumed. The belly fwells, and appears to be diftended by the elaftic fluids difengaged from the incipient decompofition, and this follows more or lefs early, according as the belly is more or lefs large and filled with fluids, the depth it is buried, and more particularly, according to the more or lefs warm temperature of the air. Hence, if all the circumftances favourable to this firft degree of putrid decompofition be united, a very fat body, the abdomen of which is expofed to moifture by being buried near the furface, and the feafon warm, will become fwelled in three or four days, whilft a meagre body, deeply inhumed, and in a cold feafon, will remain feveral weeks unchanged. It is a fact worthy of obfervation, that the ftate of the atmofphere during a ftorm has great influence in producing this fwelling, and the expreffion of the gravedigger is that the belly *bloats* at the approach of ftorms; this diftention increafes until the parts are fo extended and relaxed by putrefaction, as to burft with a fort of explofion, which happens near the umbilicus, and fometimes around the navel; from this wound runs a fanious, brownifh fluid, of a very fetid odour, and at the fame time a very mephitic elaftic fluid is difengaged, the dangerous effects of which the gravediggers have learned to dread from experience. Multiplied experience likewife, which tradition has confirmed, has inftructed them, that it is only at this period the miafmata difengaged from putrid bodies have any effect, from which real danger is to be expected. We are informed by this able chemift, that fo ftrong is this

Progrefs of decompofition in ifolated and accumulated bodies.

The danger attending them.

gas, that it ſeveral times happened when the pickaxe has accidentally ſtruck upon the lower belly, an elaſtic fluid eſcaped, from which the perſon employed was ſuddenly ſtruck down in aſphixy, and hence ariſes the dangers of the ſexton; but for a further account of this miaſma, vide article *Miaſmata.*

The diſtention and rupture of the lower belly equally takes place in bodies heaped together as in the pits, and thoſe that are iſolated; but the changes which ſucceed this firſt period of ſpontaneous decompoſition are, as has been already mentioned, very different in each.

The iſolated bodies being ſurrounded with a large quantity of moiſt earth are entirely deſtroyed, and prevented therefore from undergoing all the ſucceſſive degrees of common putrefaction; this deſtruction is the more quick, the more humid the body is, and according as the heat or coldneſs of the ſeaſon is accompanied with humidity. If, on the other hand, the iſolated bodies are dry, or emaciated; if the earth in which they are placed is acid and void of humidity; if the atmoſphere is dry, or if the rays of the ſun falling on the ſurface favours and accelerates the evaporation; all theſe circumſtances united exſiccate the bodies by abſorbing or volatilizing the aqueous parts, and by contracting the ſolids, ſo as to give riſe to thoſe ſpecies of mummies before mentioned.

In the pits, every thing is different, the great maſs of bodies heaped upon each other, and at a great depth, are not as the iſolated ones are, expoſed to the influence of external agents, or if at all, in a very inferiour degree; hence the changes they are ſubject to depend on their own ſubſtance.

When the rupture of the lower belly has taken place, the abdominal putrefaction that cauſed it appears to have already diſorganized the viſcera of this cavity, the ſtomach and inteſtines no longer form a continued mem-

branous tube. Broken in many parts, and already diſſolved into a putrid ſanies, this proceſs becomes more rapid and totally deſtroys the texture; the parenchyma of the liver, however, from it's ſolidity perhaps, ſeems to reſiſt this ſeptic menſtruum, the putrefaction does not advance to a complete deſtruction from the deficiency of humidity, and ſuch undoubtedly is the cauſe of thoſe fragments of fat that are found inſtead of all the abdominal viſcera.

The putrefaction excited in the abdomen ſoon communicates with the thorax by diſſolving the fibres of the diaphragm; hence the more or leſs complete deſtruction of the veſſels, membranes, and all the ſoft parts of this cavity, every thing announcing that it's diſorganization goes on at the ſame time as the abdomen's, or at leaſt very ſoon after; hence in this part only a few irregular maſſes of fat remain. The ſame diſorganization takes place with more or leſs energy in all the muſcular, tendinous, and ligamentous parts that ſurround the bones, according to their ſoftneſs and the quantity of their aqueous parts; the converſion into this fat ſubſtance ſucceſſively pervades every part; every thing that is membranous and more or leſs mucous is deſtroyed and diſappears, and there is no longer any trace of veſſels, nerves, or aponeuroſis in thoſe maſſes of fat that cover the bones of the extremities; all are converted into this ſubſtance.

Fourcroy, on examining the other cemeteries, found that the ſame alteration took place in the inhumed bodies as in that of the Innocents; hence the formation of this curious ſubſtance does not belong excluſively to the ſoil, but takes place perhaps univerſally where bodies are buried in large maſſes by the ſide of each other, and where, being leſs expoſed to the action of thoſe agents that operate in common external putrefaction, are only expoſed to the reaction of their own component parts on each other,

To this may be added, that this chemift likewife found, on vifiting a great number of burial places in Paris, that the change of bodies into mummies by exficcation was much more common in a great number of foils than is generally fuppofed.

The converfion into fat arrefts the putrefactive procefs.

The bodies converted into this fubftance in thofe pits that have been filled up for 40 years, prove, that once arrived at that ftate they are capable of being preferved a long time without being fubject to intire deftruction, whilft nature at the fame time, who fpares nothing, muft certainly be in poffeffion of fome means of decompofing this new fubftance, and of reducing it again to it's elements. What became of it when formed, this celebrated chemift was defirous of finding out, but the moft experienced and oldeft grave diggers were not able to afford him the leaft fatisfaction on this interefting point. Some facts however, appear to authorize a belief of his having difcovered one of the proceffes by which it is detached from the bones, and decompofed.

It's final decompofition.

In fome of the coffins that had been deranged from their horizontal to an oblique pofition from part of the earth having given way, the inferiour portion of the body was found reduced to the ftate of a fkeleton, whilft the fuperiour part ftill preferved it's maffes of fat : hence a menftrual caufe was looked for that had acted on the lower without touching the upper part.

On examination, this chemift found in the inferiour part of the coffins a brown and fœtid fluid, the earth about them was likewife moift and penetrated with the fame matter as the water in the coffins ; thefe were only to be found, however, at the bottom of the pits, and in general the fat of all the bodies that occupied this region was the fofteft, the moft changed, and the leaft in quantity. Thefe phenomena indicated to him the action of rain water which had filtered itfelf through the earth,

was collected at the bottom of the pits, where it bathed that part of the bodies within it's reach, and was imbibed by the fat matter. This account was corroborated by the gravediggers, who obferved, that after long and heavy rains the foil at the top of the pits is apt to fink for fome inches. This proves the reafon of the diminution in the mafs of bodies, the fat or foluble part of which is by degrees taken up by the water, and diftributed in more minute particles to the furrounding earth, and in which this chemift found the elements of this peculiar fubftance. Such is the progreffive fucceffion of the natural phenomena obferved by Fourcroy in the changes bodies undergo in the earth; but he very properly adds, it is only an imperfect fketch of a great picture, to which future chemifts muft add the finifhing touches.

To render it more perfect, and to know and defcribe, in all it's ftages, the flow and gradual decompofition of dead bodies inhumed in the bofom of the earth, is a lamentable tafk; it is to be indefatigable for an age in the moft forrowful inveftigations, and to live amongft tombs, and breathe the noifome effluvia arifing from them.

From the experiments which Fourcroy made on this fat matter, it appears that it is an ammoniacal foap formed of a *peculiar concrefcible oil,* united in different proportions with ammonia; and that this foap likewife contains fmall quantities of the phofphats of ammonia and lime, which, however, do not enter the faponaceous combination, but are only interpofed between it's particles; their quantity likewife varies in a fingular manner. **Experiments and obfervations on the fat.**

With refpect to the proportion of ammonia, it is almoft impoffible to afcertain how much the fat contains. It's proportion varies according to the time it has been taken out of the earth, as was proved by it's flow decompofition when expofed to the air, for the ammonia not being very adherent, an external heat above 15° is

ſufficient in time to effect it's ſeparation; the proportion likewiſe probably varies at the period of it's formation in each body, which depends in particular on the nature of the body itſelf. This matter therefore is not to be regarded as always identic, and as containing the ſame principles in the ſame proportion. The ſtate of each body, the epoch of it's burial, the ſituation, the height it occupies in the pit, the number of bodies, the diſpoſition, the greater or leſs quantity of them, muſt have great effect on the difference in the quantities of the component parts of this ſoap. Likewiſe when it is expoſed to the air on being taken from the pits, the proportion of it's principles will vary according to the place it is expoſed in, the ſize of the pieces, and the temperature and dryneſs of the air. But the moſt eſſential point to know, is, that this ſoap continually tends to decompoſition, that the ammonia is by degrees diſengaged, and that at laſt the ſebaceous matter which makes the baſis of it is left intirely naked and in the form of a yellowiſh oily concretion, ſemitranſparent, dry, brittle, and granular in it's fracture.

This fat is diſſolved neither by cold nor boiling water, but it abſorbs it with ſuch activity, and adheres to it in ſuch a manner, that it retains a great quantity which ſingularly augments it's volume. This adherence renders the water thick and viſcous, and prevents it from paſſing through the pores of the filtering paper. On the addition of ſulphuric acid, Fourcroy found, that a gas, or rather an odorous effluvium was extricated, of an inſupportable fœtidity; it was very fixed, and infected the laboratory for ſeveral days afterwards, although the windows were often kept open. This gas, therefore, is very different from that of common fat. By the nitric acid azot gas was only extricated, when the fat contained the remains of fibres; when pure it affords carbonic acid gas.

This oil, or concrete oily matter, appears to be different from all others hitherto difcovered, and is a new product arifing from the decompofition of bodies under certain circumftances, which had efcaped the attention of chemifts. For a particular account of it *vide animal oils*. Is a new production.

A fimilar decompofition appears to have taken place in a liver, which although it had been expofed to the external air, feems, by having become exficcated, to have efcaped the total decompofition which is the confequence of fuch expofure. In the beginning of the year 1785 a piece of human liver was examined by Fourcroy, which he received from Poulletier de la Salle; this liver had been expofed for more than ten years to the open air fufpended by a packthread ftring. It had at firft given out a difagreeable putrid odour, had been in part deftroyed by the larvæ of feveral infects, but without being totally diffolved by putrefaction, was become reduced by degrees to a gray friable matter, and for three or four years appeared not to have undergone any new alteration. From the firft afpect of this piece of liver it might have been miftaken for an earthy fubftance, analogous to that called mineral agaric; on a clofer examination however, fome portions of dried membranes of a brown colour were very evident, together with fome vafcular parts equally dried. When rubbed between the fingers it was greafy and foft to the touch, refembling foap. From the experiments this chemift made upon it, although he was limited as to the quantity, it appears to be analogous to what he found in the remains of the bodies above mentioned, inhumed in the cemetery at Paris, or in other words, that it was a concrete oil refembling fpermaceti. A fimilar converfion in a human liver.

1ft. A fmall portion of it placed on a hot coal at firft became foft, and exhaled an odour fimilar to burnt fat; it then melted, fwelled, and became black; on incinera-

tion, the light carbonaceous matter was converted into a white aſh.

2d. On diſtillation, half an ounce afforded a few drops of a white aqueous inſipid fluid, which was ſoon ſucceeded by a thicker fluid, and an oily white ſmoke, which was condenſed in the neck of the retort into a white concrete matter; afterwards a very putrid diſagreeable odour was perceived, the concrete oil became of a ruſt colour; carbonated hydrogenous gas was obtained. A great part of the liver had paſſed without decompoſition. The concrete oil in the neck of the retort had a lamellated and cryſtalline appearance. The products ſhowed no ſigns of either an acid or an alkali.

3d. Two ounces of hot water diſſolved a little out of one drachm. The ſolution was white and opake, had a ſlight ſoapy odour, and ſenſibly changed the ſyrup of violets green; the undiſſolved portion melted by heat, cryſtallized on cooling, had a fat odour, and inflamed; this ſlight ſolubility ſhowed it conſiſted of an oily concreſcible matter.

4th. A drachm of it triturated with half an ounce of the cauſtic lye of potaſh produced a ſlight odour of ammonia; boiled for half an hour and filtered, the ſolution, on cooling, became concrete, of a brown colour, and diſſolved in every proportion in boiling diſtilled water, leaving no reſiduum. It appeared that the whole of the liver had been diſſolved by the alkali, even it's membranous and fibrous parts. This ſolution in water frothed very ſtrongly on agitation, and on cooling depoſited ſome white light flakes. Limewater, acid, and earthy neutral ſalts precipitated them more abundantly. Hence the alkali had diſſolved a fat oily matter, and formed with it an homogeneous ſoap.

5th. Two ounces of alcohol with one drachm of the

levigated liver expofed to a gentle heat diffolved about half of it, and the refiduum treated twice more with alcohol, there only remained 20 grains undiffolved, formed of membranes and veffels that had efcaped the action of the alcohol. On the addition of water, a fubftance was precipitated in the form of white flakes, which was a concrete oil refembling fpermaceti, for which *vide animal oils*.

6th. The oil expreffed from the liver after expofure to a heat of 68° of Reaumur, in water, and rendered concrete by cold, had nearly all the properties of that diffolved in alcohol, except, firft, it had more colour, and was more fetid. Second, it contained a portion of foap, which the water had feparated from the alcoholic folution in the firft inftance.

7th. The portion of foapy matter regarded as an extract in the firft experiment, excited the attention of this chemift. It was certain that water as well as alcohol extracted it from the dried liver; but there was too little of the liver left to make any experiments upon to find out the nature of this foap. It appeared to be formed of the fame concrefcible oil as that extracted by expreffion, &c. It was even conjectured by this chemift, that before the complete alteration of the liver, and it's total converfion into a concrete oily fubftance, this oil was at firft in a foapy ftate intirely united to foda and ammonia, fince it appeared that the portion of ammoniacal foap ftill remaining in this piece of liver proved, by the ammoniacal odour difengaged by quicklime, and it's infolubility in water, to be more abundant in that portion of the liver that was deeper and lefs expofed to the air than that examined. Such are the experiments he made on this fubftance.

Hence it appears, that this concrete oily matter found in the bodies in the churchyard at Paris, and in the hu-

man liver, is the conftant product of a flow decompofition, of a long putrefaction.

Brain fimilarly converted.

Another inftance of a fimilar converfion, and in confequence the long prefervation of a certain organ of the body, is the brain. The propenfity of the brain to corrupt before moft other parts of the body is well known to diffectors, and yet under certain circumftances, it is the laft vifcus deftroyed by putrefaction; and this fingular faculty of refifting deftruction has been long ago obferved. Fabricius de Hilden relates, after George Faber, an example of this kind; the body had been buried 50 years, but the brain, he informs us, had undergone no fenfible alteration; it was white, ran like an oily matter, yet exhaled no noifome fmell. According to Theophilus Raynaud, a brain was found at Avignon equally foft and of the fame nature, whilft the body had been buried a great number of years. Peter Borell gives an account of the brains of fome maffacred people, whofe bodies had been thrown into the wells of the Dominicans, at Ceftres, that after 80 years were ftill foft and without ftench. A memorable examble of the fame kind was found in the celebrated catacombs of Kiovie, on the banks of the Borifthenes, a defcription of which we owe to Herbinius. This author afferts, that the crania of a great number of mummies perfectly preferved in thofe places, are filled with a fat and oily matter that runs from them. The refemblance of this oily matter with that already mentioned by Fourcroy, is a proof of the obfervation having been made before, although no experiments had been made upon it.

3. Aqueous putrefaction.

3. *Aqueous putrefaction.* It alfo appears, that all animal fubftances, except the bones, nails, and hair, are equally fufceptible of being converted into this fatty matter on being expofed to the effects of water. Rouelle and d'Arcet, in 1777, had obferved a phenome-

non of this kind in a dog, found under water in the Seine, all the flefh of which was converted into this fubftance. This fact has been fince confirmed by the experiments of Gibbs; for having placed at different times a couple of cows and two horfes in water, or in a running ftream, the flefh was converted into a fubftance refembling fpermaceti. The cow was placed in a fituation where the water could have accefs twice a day; over it fome loofe earth was thrown: after it had remained fome time, on pufhing a ftick through the earth to the body, a prodigious quantity of extremely offenfive air arofe, and in one year and a half the whole mufcular part was changed into this white concrete matter. The water over the animals, and for fome diftance around them, is covered with a beautiful pellicle, which is white in general; fometimes it refracts the fun's rays, producing the prifmatic colours. He likewife expofed a piece of beef in a box pierced with holes to the current, and found it had undergone a fimilar transformation in one month after.

Converfion of a dog.

Cow.

Horfe.

Fifh may alfo be changed, and it appears this concrete matter is formed in the body of an animal. Gibbs obferved, on feeing a body opened where there was a great collection of water in the cavity of the thorax, that the furface of the lungs was covered with a whitifh cruft, which he attributes to fome combination that had taken place between the lungs or pleura and the ferous fluid effufed, fimilar to that between flefh and water. Dr. Cleghorn alfo mentions a fimilar circumftance, in fpeaking of abfceffes formed in the lungs. Thefe abfceffes had fometimes emptied themfelves into the cavity of the thorax, fo that the lungs floated in purulent ferum, and their external membrane and pleura were greatly thickened, and found to be converted into a whitifh cruft, like melted tallow grown cold.

Converfion alfo of fifh.

Surface of the lungs.

The only difference on comparing this fubftance with

that formed in the cemeteries of Paris was, that where large maſſes of bodies are inhumed the concrete oily matter or ſpermaceti appears in the form of a ſoap, whilſt in thoſe immerſed in water the ammonia is not formed, or if formed, is diſſolved and carried away by the fluid in proportion as it takes place.

Human fœtus.

The human fœtus has been likewiſe found to be converted into a fatty ſubſtance from remaining in the liquor amnii, and there is a ſimilar ſubſtance to be met with in that liquid which is depoſited upon certain parts of the fœtus, called by Buniſa and Vauquelin the caſeous matter, it is ſuppoſed to be a converſion of the albumen. *Vide* article Liquor Amnii.

And the caſeous matter found upon it.

This converſion of animal ſubſtances into an oily matter reſembling ſpermaceti may be produced artificially, by means of the nitric acid; for an account of which, *vide Animal oils.*

It appears, therefore, to be this ſtate that all animal matters paſs into under certain circumſtances, *i. e.* when the external air is prevented from acting upon them ſo as to have no influence on their decompoſition, either by their being heaped together in large maſſes, by partial exſiccation, by water, or by nitric acid.

Explanation.

To account for the changes animal ſubſtances undergo on being converted either ſpontaneouſly or artificially, into this ſingular matter, which is a more ſimple ſtate of compoſition, the quantity and proportion of the primitive materials of the different animal ſubſtances ſuſceptible of it muſt be previouſly known, and ſcarcely nothing has yet been done in chemiſtry to afford this knowledge. The component parts of animal matters may, however, be reduced, as before obſerved, to oxygen, carbon, hydrogen, and azot, for the ſulphur, phoſphorus, lime, and ſoda, contribute nothing, according to Fourcroy, to their formation, if the phoſphat of lime be excepted, which

conſtitutes bones, and which has no influence on the above change. According to modern chemiſtry, the ſoft animal matters, the ſkin, muſcles, ligaments, &c. may be regarded as different kinds of carbonated oxyd of hydrogen and azot, and theſe oxyds, more complicated than thoſe of vegetable ſubſtances, tend even more on that account inceſſantly to alteration; the equilibrium of their combination is eaſily deſtroyed, and this is brought about by the leaſt changes in the temperature and humidity that ſurround them. Theſe inconteſtible principles being laid down, the decompoſition of theſe matters and the formation of the fat may be explained in the following manner.

The carbon eſcapes in great quantity in the form of carbonic acid gas, either by reacting on the aqueous part, or by ſimply abſorbing the oxygen they contain. This volatilization of the carbon with the oxygen is the principal cauſe of the conſiderable loſs animal ſubſtances undergo in their converſion into *fat*, for this laſt only forms the tenth or twelfth part of every body. The azot, a principle ſo abundant in theſe ſubſtances, combines with the hydrogen, and forms ammonia, one part of which is diſengaged in vapours, whilſt the other part remains fixed in the fat; the reſiduum of theſe ſubſtances thus deprived of a great part of their carbon, of their oxygen, and of all their azot, which laſt no longer exiſts in well formed fat, is found to contain a much larger portion of hydrogen, and it is ~~thus~~ this carbonated and ſlightly oxydated hydrogen that conſtitutes this peculiar concrete oily matter, or adipo-wax, as it has been called, the union of which with the ammonia forms the animal ſoap called *fat*. There only remains to determine whether it is the oxygen contained in the animal oxyd, or that which forms a conſtituent part of the water, that ſerves to compoſe this oxyd, in order to bring about the decompoſition: and to accompliſh this, two facts are wanting, viz. the exact proportion of

the animal oxyd, and that of the fat at the moment it is formed, and which further experiments muſt provide, although Fourcroy ſeems to be of opinion, that from the conſiderable proportion of hydrogen exiſting, whether in the ammonia formed or in the adipo-wax, it might give reaſon to ſuppoſe that the decompoſition of the water is neceſſary to this ſpontaneous operation.

Miaſmata, the ſource of infection. Having given an account of the different ſpecies of putrefaction, it will be neceſſary, before concluding the ſubject, to take a view of one of it's productions, which, from the dangerous tendency or fatality of it's nature, has at various periods of time ſpread alarm and terrour in all ages, and almoſt in all countries; this is the putrid matter which is the ſource of infection.

Amongſt the evils to which the living body is expoſed, the moſt dangerous perhaps are to be met with when the atmoſphere we breathe is rendered pernicious by the generation of thoſe deſtructive putrid exhalations which produce diſeaſes, commonly called peſtilential; and as theſe cauſes are too ſubtile to be diſcovered by any of our ſenſes, and are only made known by fatal experience, it is from chemiſtry alone we can hope for relief, and by inveſtigating the nature of ſuch cauſes, collect means in order to prevent, mitigate, or deſtroy them.

But little underſtood. Perhaps no ſubject is leſs underſtood; it may be ſaid to be involved in impenetrable darkneſs; while other ſubjects of inquiry have, in the progreſs of human reaſon, at leaſt been attempted to be inveſtigated, the remote cauſe of infection has remained a ſubject of doubt, a diſmal ſomething upon which ſcarcely a conjecture has been made, the origin of which no one durſt hazard to inveſtigate, and of which the operations appear to be capricious, multifarious and unaccountable.

Their production. It is well known, that during the ſpontaneous decompoſition of vegetable, vegeto-animal, but more particularly

of animal fubftances, a gafeous invifible matter (as before obferved) is extricated; and this is capable of acting more or lefs powerfully on the living animal body, and of producing different degrees of difeafe, from the common intermittent or ague, to the moft terrible of all diforders the plague, and when this vapour is in it's moft concentrated ftate, it's poifon is fo deleterious as to produce immediate death. This poifonous effluvium is called *miafma*, or perhaps more properly, *miafmata*. It is found to exift in low marfhy and fwampy grounds, in and about the environs of cemeteries in which numerous bodies have been inhumed, and wherever large quantities of vegetable, or vegeto-animal, or animal matters are expofed to the open air under a hot fun, fo that they may attain their higheft degree of putrefaction. It differs however in it's virulence; thus in the northern climates where the procefs of putrefaction is very flow from the acceffories being moderate, the difeafes miafmata produce are generally agues, and they feldom extend beyond dyfentery; but in the eaftern parts, as in Bengal, on both fides of the Ganges, in Louifiana, overflowed by the Miffiffippi, and in Egypt, covered annually by the Nile, when the waters retire and leave behind them the mud and flime, the great heat of the fun acting with unremitting force upon the relics which teem with myriads of animal beings, the miafmata produced are fo virulent, as to give rife to the moft dreadful peftilence, and in the moft deadly form.

Diftinction made between infection and contagion.

The term *infection* has been generally employed as fynonymous with *contagion*, and often with *miafmata*; but feveral authors of late, particularly Dr. Baily, an eminent phyfician of New York, who firft made the diftinction, have employed thefe terms to exprefs different meanings; and Webfter has adopted the fame diftinction. They affirm, that the circumftances that characterize *infection*

are, that it produces epidemics that extend over immenſe tracts of country; that it's diſeaſes are not eaſily communicated out of the peſtilential atmoſphere, and that it is mitigated, ſuſpended or deſtroyed by cold. On the contrary, the principal features of *contagion*, are, that it produces diſeaſes, but not to any great extent, that they propagate themſelves, and that it is favoured by cold. They aſſert, that the fever which owes it's origin to certain connections with the putrefaction of dead vegetable and animal matters, ſhows no diſpoſition to propagate itſelf, whilſt the fever ariſing from a connection with the living human body in a certain diſeaſed ſtate, as in meazles, ſmallpox, &c. multiplies with great activity. The one is peculiar to particular ſtates of the climate, exiſts generally in the autumnal months, in hot climates, and but rarely in cold, although it has appeared from general changes in the climate, even in the more northern regions; the other is not peculiar to ſeaſon or climate, appears oftener in winter than in ſummer, and in temperate than in hot climates; but as it depends upon adventitious cauſes, it ſometimes commits ravages in ſummer, and has even appeared in the torrid zone; the one originates from natural ſources, the other from artificial ones; ſuch is the general hypotheſis of this diſtinction, the concluſion of which is, that infectious diſeaſes ariſing from miaſmata are not communicated, whilſt contagious diſeaſes are.

Ancient and modern opinions on the contagion of peſtilential diſeaſes.

A variety of authors have contended for and againſt the contagion of peſtilential diſeaſes; among the ancients, Galen, Ariſtotle, Thucydides, Seneca, Foreſtus, Proſper Alpinus, Diemerbroeck, Sydenham, and others, contend, that the plague as well as other peſtilential diſeaſes is contagious; whilſt Procopius, and thoſe who oppoſe the doctrine of contagion, not only produce as authority, the ſilence of Hippocrates, Avicenna, and

other Arabian phyficians, on the fubject, but they affirm, that if the plague was a contagious difeafe, it would *always* infect thofe who communicated with the difeafed.

Amongft the moderns, befides the two already mentioned, Dr. Smith, of America, and Dr. Maclean, have fupported the fame opinion. The latter, in a fmall treatife, has attempted to prove that the plague, dyfentery, and other epidemics, are never propagated by contagion, for only a very fmall portion of thofe that have been expofed to the action of the effluvia of the deceafed are ever affected by the diftemper; he concludes thofe difeafes only to be contagious which muft neceffarily act and communicate the difeafe within a certain diftance, as the fmallpox, meafles, and which can only be received once by the fame perfon; whilft the others, which may affect a perfon feveral times during his life, are caufed by certain ftates or viciffitudes of the atmofphere only. He affirms, that the exiftence of contagion in the plague, dyfentery, and fevers, has been uniformly taken for granted, not only without proof, but even contrary to the evidence of numerous and convincing facts.

Although thefe and feveral other phyficians of eminence, particularly Dr. Rufh, of Philadelphia, whofe opportunities of obferving the yellow fever, or plague, of America, have been very great, are of opinion, that peftilential difeafes arifing from miafmata are not contagious; yet as fuch opinions may as yet be looked upon as conjectural, without any direct, explicit, and perfectly deciding facts, to place fuch opinions beyond the reach of all doubt and controverfy, it would be highly improper in the prefent ftate of knowledge on this fubject, for either the magiftrate or the phyfician of a board of health to diveft themfelves of the leaft precaution, either by putting an end to quarantine, or by not applying to every other

means that might place the ſafety and welfare of their fellow citizens beyond every the ſlighteſt ſuſpicion and fear of ſuch terrible calamities.

Among the numerous opinions given reſpecting the cauſes of peſtilential diſeaſes, whilſt ſome have even denied the exiſtence of a putrid cauſe, others have been ſo convinced of it's preſence as to deſcribe even it's peculiar ſmell. Thoſe who have had infectious air freſh in their noſtrils affirm, it is eaſily diſtinguiſhed from all other known odours; but the different accounts they give of it may afford ſome reaſon to ſuſpect them of errour. Some call it an earthy ſmell, very diſagreeable, that it in ſome meaſure affects the organ of taſte, even extending into the ſtomach; others have compared it to the vapours iſſuing from a newly opened grave, but without the cadaverous ſtench; others think it reſembles the effluvia of rotten ſtraw; and others again are of opinion it is like the exhalations from the confluent ſmallpox at the turn of the puſtules. The gravediggers mentioned by Fourcroy ſpoke of the odour from the burſting of the lower belly, in a ſtate of great putridity, to be a horrible ſtench; and whenever they are expoſed by an unfortunate chance to bodies in the earth, in this dangerous ſtate, ſo great is it's poiſonous activity, that if near, they are immediately ſtruck with aſphixy; if at ſome diſtance, it only gives them a ſlight vertigo, a diſagreeable ſenſation of fainting, or of nauſea, which continues ſeveral hours, followed by loſs of appetite, weakneſs, and tremours; hence ariſe thoſe diſeaſes which people are ſubject to who live in the neighbourhood of large cemeteries, a great number of whom have their countenances pale and wan, with other ſymptoms announcing the action of a ſlow poiſon. From the circumſtances, however, in which this poiſon is extricated, it is perhaps, never admitted to the organ of

ſmell in it's pure form, but generally accompanied by ſome other gaſeous and diſagreeable emanation, that may have given riſe to the different opinions of it's odour.

With reſpect to the manner in which contagion is communicated, Dr. Carmichael Smith is of opinion, that it is not only from a direct communication with the ſick that contagious fevers are propagated, but that unfortunately the perſons and clothes of thoſe who remain long in a contagious atmoſphere, and the excretions of the ſick, are capable (even when conveyed to a great diſtance, or preſerved for a length of time) of producing the ſame miſchief as an immediate communication with the ſick themſelves, and that the jail diſtemper and putrid contagion are thus frequently conveyed cannot, he thinks, be denied. Indeed, wherever a vapour can be diſtinguiſhed by the ſmell, we have the demonſtration of our ſenſes, for what a length of time, not only clothes but furniture, and even the boards and walls of houſes will retain it; therefore, in reſpect to the jail or hoſpital fever, it may be ſafely affirmed, that it not only attacks thoſe immediately expoſed to the original atmoſphere, but that this contagion may be certainly communicated by the clothes of thoſe that have been any length of time confined in it; and what is more ſurpriſing, even when the perſons themſelves are not affected. Indeed, the dread of theſe terrible diſeaſes may have probably magnified the danger beyond reality, and the riſk of propagating the contagion may not be ſo great as is ſuppoſed; phyſicians, and even apothecaries not being ſo long expoſed to this atmoſphere as to be in great danger of conveying the contagion elſewhere, yet the perſons, and eſpecially the clothes of nurſes and aſſiſtants, who are conſtantly confined amongſt the ſick, are certainly capable, according to Dr. Smyth, of communicating the diſeaſe; but he adds, that however paradoxical it may appear, he never obſerved that the

ſick propagated the diſeaſe ſo readily as the bodies and clothes of thoſe, who, though well, had been long confined in the original atmoſphere. He is of opinion, that unleſs where contagion is very powerful, it is ſeldom propagated in the open air, and he knew only of one inſtance of this, at the priſon of Wincheſter. He thinks there is but little riſk of receiving contagion from the diſſection of dead bodies, unleſs when the operator happens to cut himſelf.

The perſons moſt ſuſceptible of this contagion, Dr. Smyth aſſerts, are young perſons, particularly if they come directly from a pure air into the infected atmoſphere, thoſe whoſe minds are oppreſſed with fear or anxiety, or who have been weakened by previous illneſs; even thoſe who have been fatigued, or are faſting, receive it more readily than others whoſe ſtrength has not been impaired, or which has been again recruited with food. A moiſt atmoſphere is alſo more favourable to the communication of contagion than a dry one, and a contagious perſon becomes greatly more ſo, if his clothes are wet, and his body heated by exerciſe ſo as to be in a ſtate of perſpiration. It has likewiſe been remarked, that perſons who have iſſues are ſeldom affected by contagion.

Putrid matter, in whatever way generated, if in ſufficient quantity, has always ſome deleterious effect acting as a poiſon upon the body; and this effect takes place whether the putrid matter be generated in the body, taken into the ſtomach, or into the blood by means of a wound. It is true, the human ſtomach, and ſtill more remarkably, the organs of digeſtion of certain animals, have the power of counteracting the ſeptic tendency; but this power, at leaſt in the human ſtomach, is very limited, and when any matter, whether generated in the body or introduced from without, has acquired a degree of putridity beyond this, it occaſions nauſea, vomiting, purg-

ing, great oppreſſion at the region of the ſtomach, and often a fever, either of the intermittent, remittent, or more continued kind. Putrid matter directly introduced into the ſyſtem by means of a wound cauſes ſwelling, and inflammation of the lymphatic glands, often terminating ſuddenly in gangrene, along with the ſymptoms of a fever, greatly reſembling the hoſpital or jail fever; the ſame proſtration of ſtrength, tremors, anxiety, headach, and delirium, and all the ſymptoms of a bad putrid fever, as petechiæ, hemorrhage, indicating a certain decompoſition of the blood. The fevers that ariſe from expoſure to putrid vapour or contagion aſſume a variety of types and forms, according to the degree of putridity, ſeaſon of the year, conſtitution of the patient, &c.; but they as well as the preceding will be found to have many ſymptoms in common, and ſimilar to the jail and hoſpital fever; and in reality, all the fevers of this claſs, from the ſlighteſt vernal intermittent to the true plague, are, as Dr. Smyth obſerves, only different ſhades or varieties of the ſame diſeaſe, and productions of one common cauſe, viz. putrefaction.

What that ſubtile or powerful vapour, or whatever elſe it may be, is that ariſes during the putrefactive proceſs, and acts in the form of ſuch a powerful poiſon, is unknown. Various, however, have been the opinions on the cauſe of peſtilential fevers.

Ancient and modern opinions on peſtilence.

On extending our inveſtigation towards antiquity reſpecting the origin of peſtilential diſeaſes, we ſhall find that ſuperſtition was the firſt to account for them, by aſcribing peſtilence to the immediate exerciſe of Divine Power. It was ſuppoſed that it was one of the judgments that God inflicted on mankind in his wrath, to puniſh them for their iniquities; thus when ~~Daniel~~ David was ſummoned to receive his puniſhment for numbering the

Scripture.

children of Iſrael, having been permitted to make choice of the three greateſt calamities, he preferred, for a pious reaſon, peſtilence to either famine or the ſword; and 70000 of his ſubjects periſhed. "I will ſmite the inhabitants of this city both man and beaſt, they ſhall die with great peſtilence." 2 Sam. 24. Jerem. ch. 21.

Homer. In perhaps the oldeſt hiſtorical account of mankind, after the Bible, we are informed by Homer, that a plague raged during the ſiege of Troy, and peſtilence is aſcribed by the poet to extreme heat under the influence of the dog-ſtar, and alſo to vapours.

"As vapours blown by Auſter's ſultry breath,
"Pregnant with plagues, and ſhedding ſeeds of death,
"Beneath the rage of burning Syrius riſe."

Pope's Hom. Il. b. 5. 1058.

Hippocrates Hippocrates attributes peſtilential diſeaſes to putrid air, which infects all animals that breathe in it. "Firſt," ſays he, "I will begin with the moſt common febrile diſeaſe, which in ſome meaſure accompanies all diſeaſes; for there are two ſorts of fevers, one that is promiſcuous, and common to all, called the plague; the other, by reaſon of unhealthy diet, is peculiar only to ſuch as uſe that diet; but of both theſe kinds of fevers the *air is the ſole author and cauſe*; the common fever or plague therefore happens to all, becauſe all breathe the ſame air; and it is certain, that the ſame air being mingled in ſimilar bodies muſt beget the like fevers." On demanding why infectious diſtempers ſeize not all animals alike, he anſwers, that when the air is filled with ſuch filth and pollutions as are noxious to human nature, men only fall ſick, but when it is hurtful to any of the other ſpecies of animals the diſeaſe ſeizes that ſpecies only. Hippocrates, however, ſeems to have been aware that there was ſomething elſe neceſſary, for he ſpeaks of το θειον or ſome divine

principle in the air, which has been fuppofed to mean an epidemic conftitution, arifing from changes in the atmofphere produced by unknown caufes.

According to the obfervations of Ariftotle, peftilence may owe it's caufe to a hot and dry fouth wind. Ariftotle.

Galen, who lived at Rome in the reign of Marcus Antoninus, whilft a raging plague was defolating that city, is of opinion, that Hippocrates was miftaken in afcribing the caufe of epidemic difeafes to the air only, and obferves, that peftilential fevers fometimes proceed from a great abundance of humours, whenever thefe have acquired from the ambient air the leaft tendency to corruption. He attributes alfo thefe difeafes not only to the air, but to unwholefome food and vitiated waters. Galen.

Ammianus Marcellinus mentions a plague in the city of Amida, in Perfia, when befieged by Sapor, about the middle of the fourth century; it arofe from the corruption of numerous dead bodies which lay unburied in the ftreets. He then proceeds to give the opinions of others on the fubject, as follows: "Philofophers and eminent phyficians have taught, that peftilence is produced by excefs of heat or cold, of drought or moifture. Hence thofe that live near wet and marfhy places are fubject to coughs, difeafes of the eyes, &c. Thofe, on the other hand, that refide where the heat is great, are troubled with febrile complaints, and in proportion as the matter of fire is more active, drought is more rapid in deftroying life. Others are of opinion, that air, like water, vitiated by the effluvia of dead bodies, or fimilar fubftances, is deprived of it's falubrity, or at leaft, that a fudden change of air will produce the more flight complaints. Some alfo affirm, that the air, rendered grofs by a denfer vapour from the earth, clofing the pores of the body, and checking perfpiration, becomes fatal to the lives of others, for which reafon thofe animals which are continually Marcellinus.

bending towards the earth are the firft victims to peftilence, as Homer teftifies, and which is proved by many examples during the prevalence of peftilential difeafes."

Ætius. About the clofe of the fifth century, Ætius, who was an eminent phyfician, has compiled the opinions of his predeceffors on epidemic difeafes. "Thofe are called fo," fays he, "which originate from a common caufe, as bad food, or water, immoderate grief, or want of cuftomary exercife, hunger, or repletion, efpecially when abundance fucceeds extreme want. But the nature of the country often caufes epidemic difeafes; the air we breathe being vitiated by the evaporation from putrid fubftances, fuch as multitudes of dead bodies after battles, marfhes or ftagnant water in the vicinity, which emit poifonous and fetid vapours. This caufe is in continual operation."

Profper Alpinus. The Greeks called thofe difeafes that operated univerfally ἐπιδημικοι, and if at the fame time they were very deftructive, they had the name of a plague, by the Greeks, λοιμος, by the Latins, peftis, à pafcendo or peftilentia, according to Ifidorus, quàfi paftulentia, quòd veluti incendium depafcit, becaufe it confumes and devours like a burning flame But fince, although at what time is difficult to fay, a difference has taken place between *peftis* and *peftilentia*. It is, however, found in the works of Profper Alpinus, a Venetian phyfician, who wrote about the clofe of the 16th century. This author maintains, that peftilent fevers are occafioned by local caufes, as vitiated air, and by peculiarities of feafon, as extreme heat and humidity; but he afferts, that the plague in Egypt rarely proceeds from corrupted air, and never except after an unufual flowing of the Nile, and concludes, it is ufually imported.

Diemerbroeck. An eminent Dutch phyfician of the laft century, Diemerbroeck, affigns three caufes of the peftis or true plague. 1. The juft anger of Heaven, provoked by ex-

halations from the ſinks of our ſins and abominable deeds. 2. A moſt malignant, poiſonous and deadly peſtilent germe, like a ſubtle ferment or leaven, ſent from Heaven in a very ſmall quantity, diffuſing itſelf through the air like a ſubtle gas, and rendering it impure. This gas, he ſuppoſes, ſpreads over many regions, and impreſſes, by it's numerous particles on the air, an infection like poiſon, which affects people.

He maintains the diſtinction mentioned by the laſt author, and ſuppoſes, that peſtilentia is produced by exhalations and intemperate ſeaſons; whilſt the plague, he contends, cannot be occaſioned by thoſe cauſes, though they may aſſiſt the germe or general cauſe.

Van Helmont.

According to Van Helmont, a Flemiſh writer of the laſt century, but one, the plague cannot be aſcribed to the unſeaſonable changes of times, nor to putrefaction; but that it's poiſon is a ſecret, that the matter of that diſeaſe is a wild ſpirit tinged with poiſon, exhaling from a diſeaſed perſon, or drawn inwards from a gas of the earth, putrefied by continuance, and receiving internally an appropriate ferment, and by degrees attaining a peſtilential poiſon in us. The remote, crude, and firſt occaſional matter of the peſtilence, is an air putrefied through continuance, or rather a heavy putrefied gas, which putrefaction of the air hath not the 8200th part of it's ſeminal body. When we compare this unintelligible explanation of this alchemiſt with the ancient method of aſcribing the cauſe of peſtilential diſeaſes to the extravagant ſyſtem of judicial aſtrology, the latter is by far the moſt ſatisfactory; both of them perhaps equally unphiloſophical. The author, however, contends againſt a more ancient ſuperſtition, that the plague is not ſent down from Heaven, but that popular plagues draw their firſt occaſional matter from an earthquake, and from the conſequences of camps and ſieges.

Hodges. Hodges, who wrote a treatife on the great plague in London in 1665, obferves, that the air fuffers fome effential alteration which is neceffary to favour the propagation of peftilence. The nitro-aerial principle, which caufes or invigorates animal and vegetable life, fometimes becomes imperfect, degenerate or corrupt, being tainted with fomething pernicious to vitality. He calls it poifonous, and obferves that it proves injurious to trees and cattle, as well as to man. He fuppofes the corrupting principle to be a fubtle aura, or vapour, extricated from the bowels of the earth.

Van Swieten. According to Van Swieten, the caufe of epidemics is in the hidden qualities of the air, and is inexplicable.

Sydenham. Sydenham agrees with Diemerbroeck, and Van Swieten, in afcribing peftilence to occult qualities in the air. Of the fame opinion is Fernelius, Sennat, and Stenkius.

Mead. Mead afcribes the plague to the putrefaction of animal fubftances and unfeafonable moiftures, heats, and want of winds; and affirms, that no kind of putrefaction in European countries is ever heightened to a degree capable of producing the true plague. He is furprifed that authors fhould have recourfe for an explanation of the caufes to hidden qualities, fuch as malignant influences of the heavens, arfenical, bituminous, or other mineral effluvia, with the like imaginary or uncertain agents. He affigns three caufes. 1. Difeafed perfons. 2. Goods tranfported from infected places. 3. A corrupted ftate of air. He does not, however, deny all latent diforders in the air, but confiders them as fecondary caufes only, increafing and promoting the difeafe when once bred, and thinks infection to be the means of it's propagation. In this he differs greatly from Diemerbroeck, who utterly denies that the difeafe is originally derived

from infection, although he agrees that it may be afterwards communicated from perfon to perfon by contact, or near approach. Diemerbroeck alfo maintains the latent qualities of the air to be the *principal* caufe of the plague, or caufe, *fine qua non*. Mead fays, the plague is never originally bred with us, but always brought accidentally from abroad.

Mackenzie, who gave an account of the plague in Conftantinople, fuppofes the difeafe to proceed from venomous moleculæ, lodged in wool, cotton, hair, leather, and fkins, in houfes not well cleanfed after peftilence. He thinks the air no otherwife concerned in producing the difeafe, than as a vehicle to convey the venomous particles from one body to another. Mackenzie.

The idea of Dr. Chandler greatly refembles that of Dr. Mackenzie, with refpect to the origin of plague. He fays it might be perhaps truly defined, 'a difeafe arifing from certain animalculæ, probably invifible, which burrow and form their nidus in the human body. They always fubfift in places fuited to their nature. The fpecies imported from Smyrna are commonly deftroyed by intenfe heat. The pores of the fkin opened by the weather, readily admit them. Chandler.

Gibbon the hiftorian afferts, that the plague arifes from hot, damp, ftagnant air. Gibbon.

The Abbe Fourmont, that it originates from famine. Fourmont.

Dr. Mitchill, that the gafeous oxyd of azot or nitrogen is the matter of contagion; this is the dephlogifticated nitrous air, difcovered by Prieftley, it fupports flame and extinguifhes life. Dr. Mitchill.

It might have been expected that in defcending to modern times, a more fatisfactory account of the poifonous matter, whofe action has been fo very inimical to the human fpecies, would have been given by phyficians, but it appears, that no method has yet been found

out to render this invifible agent pervious to the fenfes, and that every thing refpecting it hitherto has been either fable or conjecture. If, however, this terrible enemy has efcaped the inveftigation of the philofopher, means have been employed to render the poifon ineffectual, and to difcover by chemical reagents what are the moft effectual fubftances to counteract it's effects, either by decompofition, or chemical union.

Ancient ufe of fumigations, defcending to modern times.

Hippocrates, we are informed, in order to deftroy the peftilential particles of the air, made ufe of fcented wood, which he caufed to be burned in piles placed at the corners of the ftreets, but the remedy appears to have been equally as inefficacious as the fmoking of tobacco, the thieves vinegar, with the reft of the numerous noftrums and amulets that have fucceeded each other at different times. It is readily conceived why fumigations, and fubftances yielding ftrong odours, were firft employed for this purpofe. The plague, and other difeafes, attended with great mortality in ancient times, being confidered by the fuperftitious world, as judgments fent by the hand of divine vengeance, to fcourge the human race for their fins, as before obferved, facrifices and expiations were made to the gods, to deprecate their wrath, and atone for the guilt of mankind. Sweet fmelling herbs and flowers, and aromatic gums, as myrrh and frankincenfe, were therefore burnt during thefe ceremonies; and as the whole were of an agreeable odour, and overpowered the offenfive effluvia of difeafed or corrupted bodies, it was natural for thefe ignorant people to believe, that fuch fumes, by deftroying the fmell, deftroyed likewife the polluted effluvia. Another circumftance obferved by Dr. Trotter might have given rife to fimilar means. It was believed that the peftilential difeafes were the offspring of putrid and of putrefying animal and vegetable fubftances, and thefe fubftances

they ſaw became the nidus and the nouriſhment of numerous young inſects; whence they concluded, that their generation was ſpontaneous. To deſtroy theſe animalculæ, which in hot countries increaſe in ſuch numbers, and which now on the wing they conſidered as polluting the atmoſphere, brimſtone and fire would ſoon be reſorted to, as it was known, that no animal could approach their conflagration, ſo that every article that yielded either agreeable odours or pungent vapours was employed; hence the hyſſop of the wall, the cedar of Lebanon, the camphire of Engedi, ſpices and the pitch of Norway, and the tobacco of Virginia, ſwell the antipeſtilential catalogue; and the fumigating ſubſtances have been handed down from the Jews, the Greeks, and the Romans, through the Arabian phyſicians and the dark ages of Europe to the moderns, and have maintained their reputation and character, amidſt all the viciſſitudes of human opinions, and the fleeting duration of medical theories. Nobody, till lately, has queſtioned a practice ſanctioned by the authority of antiquity, and the univerſal ſuffrage of modern phyſicians, until the beautiful diſcoveries of pneumatic chemiſtry, which explained the nature and compoſition of elaſtic fluids, invited the chemical philoſopher to apply his new acquired knowledge to the detection of the cauſes of peſtilential diſeaſes, and to find out the beſt and moſt ſuitable prophylactics againſt them.

Until a knowledge of the different airs that compoſe our atmoſphere, and the various gaſes that ariſe from ſpontaneous or artificial decompoſition, began to prepare the chemiſt for future inveſtigation, little could be expected from any other branch of philoſophy, but no ſooner did the experiments of Black, Cavendiſh, Prieſtley, Lavoiſier, and Berthollet, afford a light into the unexplored regions of the aerial world, than a new oportu-

Chemical method of deſtroying miaſmata.

nity prefented itfelf of inquiring into the nature and properties of thofe effluvia, that arofe from the putrefaction of animal and vegetable fubftances, and which have in all ages been more or lefs looked upon as the origin of peftilential difeafes.

Morveau. Amongft thofe who made the firft attempts to render the poifonous vapour of peftilence ineffectual by chemical decompofition, Morveau, a chemift of Dijon, is perhaps the beft deferving of being recorded. He appears to have confidered this matter as compofed of volatile alcali, and an acrid animal oil in a gafeous, or aeriform ftate; and he informs us, that in May, 1773, the cathedral church of Dijon was found to be fo very infectious and noifome, from the numerous inhumations, as to be no longer fafe to frequent, whilft various fubftances had been employed to deftroy it's cadaverous fmell, fuch as large quantities of aromatics, vinegar, nitre, but without any effect, and under thefe circumftances this chemift was applied to.

It is a well known property of the muriatic acid, to take a gafeous form as foon as it is difengaged from it's combinations, but without lofing it's acid character, or having it's energy diminifhed, and this was found to be of great ufe in purifying and deftroying the infection of a mafs of air, when loaded with putrid vapours. The method the commiffaries of the Royal Academy at Paris had employed, in their report on the prifons of that city, was to add vitriolic acid to common falt, which difengages the muriatic acid in the form of white vapours, that immediately expand throughout the whole room or place where the procefs is made; and this has been found, to ufe the expreffion of thefe commiffaries, to *neutralize the putrid* miafmata, and they recommend, as foon as the vapours are paffed away, the doors and windows to be left open for two or three days, fo that the

ſlight odour of the marine acid remaining may be diſſipated, after which they found not the leaſt danger of immediate habitation.

Morveau, with this previous knowledge of the good effects of this acid, applied it to the preſent inſtance of the cathedral. He ſuppoſed, that the acrid animal oil of the putrid effluvia, and which particularly affected the organ of ſmell, was ſupported in it's gaſeous form by the volatile alcali, and that if a decompoſition could be effected, the heavy fetid oil would fall down and be rendered inert. The vitriolic acid, formed by the combuſtion of ſulphur, he knew would to a certain point accompliſh this object; but as it riſes very little, and after ſeizing upon the humid vapour, which it does with great avidity, loſes it's heat and falls down again, it was incompetent to the taſk. He therefore placed a glaſs veſſel prepared for the purpoſe in the middle of the church, put into it 6lb. of common ſalt ſomewhat moiſtened, and poured 2lb. of common vitriolic acid upon it, and immediately retired. He informs us, that he was ſcarcely got four paces, before a column of vapours of the muriatic acid had reached the ceiling of the church, and two hours afterwards, it was perceived through the keyhole of the moſt diſtant door. In about twelve hours all the doors were opened for the air to be cleanſed of any remaining acid, but there was no longer any trace of putrid odour to be perceived.

The following year, another proof of the ſucceſs of the ſame method was made in the priſons of Dijon. We are told, that 31 priſoners had died of the peſtilential diſeaſe, called the jail fever, in leſs than three months, and means had been in vain attempted to deſtroy the cadaverous odour, by burning ſtraw in the priſon, but in twelve hours after the operation of the muriatic acid, the fetid odour was entirely deſtroyed, the danger of in-

habiting it no longer exifted, and from that moment, the epidemic fever entirely ceafed.

Others who have been employed in purifying infectious places, in confequence of epidemic difeafes, recommend the fame procefs, and advife it to be ufed as a precaution every year to preferve in particular the falubrity of prifons, and deprive them of infection.

Another form in which this acid has been employed, is in it's dephlogifticated ftate. According to Fourcroy, whatever care is taken to keep anatomical theatres clean and inoffenfive, either by fprinkling with vinegar, or by fumigations, it is found very incapable of preventing the dangerous effects arifing from a large mafs of matter, in a ftate of putrefaction; this enemy is the more terrible to anatomifts, whofe occupation is to refide within the reach of it's action, and the frequency of accidents from this fource every year is well known. To oppofe, therefore, an impenetrable barrier to this deftructive agent, to prevent it's difaftrous effects on thofe occupied in anatomical purfuits, and to deftroy the germe of putrid and frequently fatal difeafes, which thefe miafmata occafion, this chemift recommends the oxygenated muriatic acid, which he found to be the beft fhield againft the poifon of all animal putrefaction. He was led to it's ufe, from the effects it was found to have on odours of all kinds. Aromatics, the acid antifcorbutic, the poifonous narcotic, hepatic and fulphureous odours, were all deftroyed by this vapour, and as it acts immediately on the odorous principle, alters it's nature, and changes rapidly the order of it's compofition, it was fuppofed, that it was likewife capable of oppofing thefe dangers arifing from the miafma of putrifying bodies, and this chemift informs us, experience confirmed the fuppofition.

Fourcroy.

Another acid which was firft employed by Dr. Carmichael Smyth, to deftroy the contagion of the hofpital fever, or jail diftemper, is the nitrous acid. The caufe of this fever he attributes to putridity. As a proof of this, he obferves, that this difeafe is conftantly produced where a number of people are fhut up together in a clofe place, without the greateft attention to cleanlinefs and renewal of the air. Now it is well known, that all the excretions of the human body have already made a certain advance or progrefs towards putridity, and that when placed in certain circumftances favourable to putrefaction, they foon become highly putrid; amongft thefe, he thinks none is more highly animalized or more fufceptible of becoming putrid than the perfpiration or vapour iffuing from the furface of the body and lungs; hence the animal perfpiration may generate contagion, which contagion is found to fhow it's baneful effects more quickly and forcibly in proportion to it's quantity, and it's being placed in circumftances the moft favourable to putrefaction; confequently, in proportion to the fize and clofenefs of the place, the temperature and moifture of the air, and the additional or acceffory putrid matters with which it is combined; whilft on the contrary, the formation of this contagion is prevented by all thofe means that renew the air, and carry off the perfpiration, or prevent it's tendency to putrefaction. In order to deftroy the fceptic nature of this jail or hofpital contagion, which he looks upon as one of the moft fubtile and powerful vapours of the putrid kind, from it's immediate and deftructive effects on the human body, feveral ways were employed. At firft, when Dr. Carmichael was requefted to undertake the cure of this difeafe, which was raging with great violence during the fpring and fummer of 1780, amongft the Spanifh prifoners, confined

Dr. Carmichael Smyth.

in the King's houfe at Winchefter, he found great benefit from cleaning the parts of the prifon affected by the contagious matter, wafhing the hammock pofts with diluted muriatic acid, and throwing it by machines to the upper part of the pofts, and even as high as the ceiling, at the fame time the prifoners were well wafhed; but the moft important part of the method he employed is the nitrous acid, which he informs us he ufed in two different forms, either in vapour from the yellow or fmoking nitrous acid, or from nitre difengaged by the vitriolic acid; by which practice, both in hofpitals, and in private practice for 16 or 17 years, he has obtained the moft decifive evidence of it's effects, in preventing the fpreading or farther communication of contagion. Having found, that the moft highly contagious fevers in hofpitals do not effect the patients in general, lodged in the fame ward, but only the nurfes or thofe who affift them, or thofe who lie in beds contiguous to the fick, he has repeatedly prevented the farther fpreading of the difeafe, by placing gallipots filled with the fuming nitrous acid, betweed the beds of the fick, and of thofe who were not yet affected by the contagion; and in private practice, where the nitrous acid has been conftantly ufed as a fumigation, he has not known one inftance of a contagious fever having been communicated, even to a nurfe or to an attendant. He is of opinion, that the well known efficacy of the fulphureous acid in deftroying contagion, is a fufficient reafon for it's being continued as a fumigation for clothes, furniture, &c.; but as the nitrous acid is attended with no rifk, or inconvenience to the refpiration, and appears of fufficient efficacy to prevent the progrefs of the contagion, it is the proper antidote to be applied in all fituations where perfons are neceffarily prefent; likewife in purifying empty hofpitals or prifon wards, or fhips, as it is equally

efficacious with the fulphureous, it's vapour more volatile and penetrating, and it does not leave the difagreeable fmell which fulphur does, when burnt. To obtain the nitrous or marine acid, in a ftate of vapour, as Dr. Smyth is of opinion, that all the mineral acids will deftroy contagion, and are much more powerful than the moft concentrated vinegar, he advifes to decompofe nitre or falt by heated vitriolic acid, half an ounce of which is put into a crucible, glafs, china cup, or deep faucer; this is warmed over a lamp, or in heated fand, adding from time to time fome nitre, or common falt; thefe veffels ought to be placed at 20 or 30 feet from each other, according to the height of the ceiling, or virulence of the contagion. In hofpitals or prifons, the lamps or veffels containing heated fand may be placed on the floor; in fhips, it will be better to hang them to the beams by waxed filk cords. As fumigating with nitrous acid is attended with no inconvenience, the procefs fo fimple, and the materials fo cheap, it fhould be employed as a means of prevention, for fome hours every day, in tranfports with troops on board, and in crouded hofpitals; and if there be any appearance of contagion, the fumigation fhould be executed with more care and attention, and the vapour confined for feveral hours at a time. Fumigating veffels or lamps fhould alfo be placed contiguous to the hammocks, or beds, of perfons affected with any contagious or putrid diftemper, and by fuch precautions great mifchief may probably be prevented.

A corroborating inftance of the effect of the nitrous acid in ftopping contagion is defcribed by the fame author. The experiment was conducted by Menzies, furgeon on board the Union hofpital fhip, which contained nearly two hundred fick, of whom one hundred and fifty were in different ftages of a malignant fever, and highly contagious,

as appeared from it's rapid progrefs, and fatal effects. The utenfils and materials for fumigation confifted of a quantity of fine fand, twenty-four great earthen pipkins, and as many fmall common tea-cups, with fome long flips of glafs as fpatulas, the concentrated vitriolic acid, and a quantity of pure nitre in powder. The ports and fcuttles being clofe fhut up, the fand, which had been previoufly heated in iron pots, was fcooped out into the pipkins by means of an iron ladle, and in this heated fand in each pipkin, a fmall tea-cup was immerfed, containing about half an ounce of concentrated vitriolic acid, to which, after it had acquired a proper degree of heat, an equal quantity of levigated nitre was added gradually, and the mixture ftirred with a glafs fpatula, until the vapour arofe from it in confiderable quantity. The pipkins were then carried through the wards by the nurfes and convalefcents, walking about with them in their hands, occafionally putting them under the cradles of the fick, and in every corner where any foul air was fufpected to lodge. In this manner the fumigation was continued, until the whole fpace between decks was, fore and aft, filled with the vapour, which appeared like a thick haze. The body clothes and bed clothes of the fick were likewife expofed to the nitrous vapour as much as poffible, the dirty linen removed, and immediately immerfed in a tub of cold water, dried, and then fumigated before taken to the wafh-houfe, a precaution very neceffary in every infectious diforder; due attention was alfo paid to cleanlinefs and ventilation. The fumigation took up about an hour, and in an hour afterward the vapour having entirely fubfided, the frefh air was freely admitted by throwing open again the ports and fcuttles. The fumigation was repeated morning and evening, and it's pleafing and immediate effect in deftroying the offenfive and difagree-

able ſmell, ariſing from ſo many ſick crowded together, was very perceptible; and ſo great was the benefit it produced, that not one of the attendants on the ſick, or any of the ſhip's company, was attacked with the diſorder after it was firſt begun.

The ſucceſs of the ſame plan is likewiſe further atteſted by the ſubſequent letters of the ſame ſurgeon, and Baſſan, who ſucceeded him; and from a ſimilar experiment made on board ſome of the Ruſſian men of war.

In making uſe of the nitrous vapour, it is neceſſary to diſtinguiſh that which is good from that which is hurtful. The vapour made uſe of by Dr. Smyth, by means of the vitriolic acid, poured on nitre in earthen or glaſs veſſels, is white, highly dephlogiſticated or oxygenated, and mixed with a large quantity of pure dephlogiſticated air; and this fume is not only not ſuffocating, but has a pleaſant ſmell.

The vapour, however, which ariſes in the uſual proceſs of diſtilling aqua fortis, as it is done in iron veſſels, or which exhales during the ſolution of metals by the nitrous acid, is of a red colour, has been called phlogiſticated nitrous acid vapour, and is highly ſuffocating and noxious; ſo that in preparing this vapour caution muſt be uſed, that no metallic or inflammable ſubſtance be admitted to the acid either by means of the veſſels, or uſing iron ſpatulas or implements.

By this fumigation, therefore, it appears, that the proceſs is both ſimple and eaſy; and although the vapour is extremely powerful and penetrating, the ſick of every deſcription are obſerved to bear it with little or no apparent inconvenience; and as it is found to purify the air from the diſagreeable effluvia produced by ſo many people crowded together in a confined ſituation, of completely deſtroying the offenſive ſmell, and contagious matter ari-

ſing from putrid animal effluvia, or other animal matters; it will be peculiarly advantageous on board of ſickly ſhips and hoſpitals, as well as priſons, where the clothes of the crew or patients may be fumigated at the ſame time as the apartments, without any riſk of fire. At the ſame time it appears, that the advantages of the fumigation are not only experienced by thoſe in health, whom it preſerved from the baneful effects of the fever, but the ſick and convaleſcents derived an almoſt equal benefit from it; the ſymptoms of the diſeaſe were meliorated, and loſt much of their malignant appearance, and the advantage of an air pure and free from ſtench to convaleſcents muſt be very great.

Dr. Carmichael Smyth has, in a *deſcription of the gaol diſtemper*, given an examination of the different means hitherto employed to deſtroy the gaol contagion. Theſe he arranges under two claſſes, viz. the phyſical and the chemical. He ſays, that contagions, whether ſpecific or putrid, are either checked or completely deſtroyed by the extremes of heat and cold; and by a free expoſure to air and water are ſo diluted or diſſolved as to loſe their noxious quality. Theſe four are therefore phyſical agents. A degree of heat nearly equal to that of the oven is found neceſſary for the complete deſtruction of contagion, and may be uſed in purifying clothes, furniture, &c. Heat is likewiſe, when judiciouſly managed, a check to it's progreſs; for as cloſeneſs and dampneſs are favourable to the production and ſpreading of contagion, drying and rarifying the air, by counteracting theſe, muſt be, at leaſt ſo far, proper antidotes. Independent, however, of heat, an open fire, eſpecially where the fuel is burnt in a narrow flue, is of great benefit, as being one of the beſt ventilators. The degree of cold neceſſary to deſtroy contagion is probably, like the degree of heat, inconſiſtent with

life, and therefore, although we hear of contagion having been checked or fuppreffed by cold, there are few inftances, if any, of it's being completely deftroyed by it.

That noxious vapours are hurtful only when concentrated, and are harmlefs when diffufed, are facts univerfally admitted; and hence clothes, bedding, or other things to which contagion adheres, are purified by a certain length of expofure to the open air, or to a current of water; but as the time requifite for this mode of purification is uncertain, and as contagious clothes and goods, &c. cannot always be expofed in a proper manner, the more expeditious means which chemiftry affords muft be had recourfe to: and as Dr. Lind has very properly remarked, that no ventilation or admiffion of air or water into prifons or hofpitals can remove or deftroy contagion when once prefent, although both may be ufefully employed in blunting it's force, chemical agents are abfolutely neceffary. Thefe Dr. Smyth examines. The chemical agents hitherto employed for deftroying contagion, are,

1. *Burning fulphur with charcoal, or with arfenic.* The vapour from the burning of fulphur is remarkably volatile and powerful, and it's effect in deftroying contagion has been long eftablifhed, but as even in fmall quantities it affects refpiration, producing fuffocation and death, it can only be employed for fumigating clothes, furniture, or empty apartments. The occafional addition of arfenic feems to have been made by Dr. Lind, with a view of increafing the deleterious quality of the vapour; but it appears unneceffary, as the fulphureous acid is fufficiently ftrong, and perhaps the vapour of arfenic is too heavy to rife with the acid of fulphur.

2. *Burning or deflagrating nitre.* As there is no nitrous acid produced, it can be of no ufe except fo far as the oxygen may be of fervice.

3. *Burning gunpowder* and port-fire (one half ſulphur, one quarter nitre, and as much charcoal) can be of no uſe.

4. *Tar*, *tobacco*, and *wood* when burnt (although Dr. Lind appears to have had a high opinion of the ſecond, and looked upon the third to be one of the moſt powerful means of deſtroying contagion) cannot be of any ſervice.

5. *Vinegar*. This, although much boaſted of, Dr. Smyth never ſaw of any ſervice; but the ſteam when united with camphor affords a reviving ſmell to patients. Waſhing the furniture, floors, and walls with vinegar, is little better than common water, and the ſame may be ſaid of white waſhing, and oil painting.

The moſt powerful agents, perhaps, after fire, are the mineral acids, particularly when in a ſtate of vapour, with the different gaſes or permanently elaſtic fluids produced by them; and as they are known to have a great influence over putrefaction, and thoſe other ſpontaneous changes which vegetable and animal matter, deprived of life, undergoes, they certainly muſt be very efficacious in deſtroying the gaol contagion, which, according to Dr. Smyth, is a vapour produced by putrefaction.

As the volatile ſulphureous acid vapour, though effectual in deſtroying contagion, cannot be employed except in ſituations from which people can be removed, Dr. Smyth made ſome experiments with the vapours of the other acids upon mice, birds, and upon himſelf; and found the different acid vapours, in reſpect to the ſafety with which they can be breathed, may be arranged in the following order:

1. *The vapour of nitrous acid, ariſing from nitre decompoſed by vitriolic acid.* This is perfectly harmleſs in any quantity in which it may be required, there not being the leaſt riſk in breathing it. For this purpoſe, the fumigating lamps ſold at Moyſer's, in Greek ſtreet, Soho, may

be employed, a great number of which are ſold to the navy, but they would anſwer much better if the ſaucer was deeper; and if, inſtead of a place for a lamp, there was a box proper for containing hot ſand, in which the ſaucer might be placed. This nitrous vapour appears to be the *deſideratum* ſought after by Dr. Lind.

2. *The vapour of nitrous acid in it's fuming ſtate, or when the nitrous acid is mixed with nitrous gas.* This, though more pungent than the firſt, Dr. Smyth believes may be employed with the greateſt ſafety, having never known any inconvenience from uſing it. But as it was more difficult to pr cure, and is attended with greater trouble and expenſe, he has always uſed the firſt.

3. *The vapour of marine acid, ariſing from common ſalt, decompoſed by vitriolic acid.* This, though more ſtimulating and more apt to excite coughing than the nitrous, may be ſafely uſed, at leaſt in a moderate quantity, where people are preſent; and where nitre cannot be had, Dr. Smyth would not heſitate to employ it.

4. *The vapour of nitrous and marine acids from nitre and common ſalt by vitriolic acid.* This, on being heated, was more pungent than the pure marine acid, and therefore unleſs it be found more efficacious in deſtroying contagion, ſhould not be uſed where people are preſent.

5. *The vapour of ſulphur burnt with one-eighth part of nitre.* This can only be uſed with ſafety when there are no people preſent; hence muſt be ſolely confined to fumigating empty apartments, clothes, furniture, &c.

6. *The vapour of ſulphur burnt with charcoal.* This ſhould never be employed, as the carbonic acid may do harm, and never can have any effect on contagion.

7. *The vapour of oxygenated marine acid, by diſtilling marine acid from mangane ſe.* Dr. Smyth ſays, he only knows it is extremely deleterious.

Dr. Smyth found the marine acid, when properly diluted, proved completely effectual in deftroying the contagion at Winchefter prifon, by wafhing the hammock pofts, walls, and floors of the prifon ward, as well as the other furniture with it; and in this refpect it is certainly more powerful than the moft concentrated vinegar.

French chemifts, their method by marine acid vapour.

Since Dr. Smyth's experiments upon the mineral acids, the French chemifts and phyficians have publifhed a paper on the means of deftroying contagion. It is entitled, "*Inftruction fur les moyens d'entretenir la falubrité, & de purifier l'Air des Salles lans les Hôpitaux militaires de la République, fait au Confeil de Santé, le 5 Ventofe, l'an 2d de la République.*" From this *mémoire* it appears, the French phyficians, inftructed by Guiton of Dijon, have lately made trial of the vapour of marine acid in their hofpitals, and have found it equally as effectual in deftroying contagion as the fulphureous, and, as being more volatile, perhaps even preferable for the purpofe of purifying hofpital wards. They alfo remark, that in a fmaller proportion, it may be fafely ufed in hofpital wards, even where people are prefent, and the experiments of Dr. Smyth prove the fame. The method the French phyficians employed to obtain the marine acid vapour, is either by employing the fuming marine acid, or the acid detached from it's alkaline bafis by vitriolic acid, ufing a confiderable degree of heat for this purpofe. The procefs for a room containing from forty to fifty beds is, after having taken out the patients and clofed the doors and windows, to heat nine ounces of muriat of foda (common falt) flightly moiftened with half an ounce of common water, and pour upon it four ounces of fulphuric acid or common oil of vitriol, having previoufly placed the apparatus in the middle of the room. In an inftant the fulphuric acid acts upon the common falt, and the ma-

rine acid expands itfelf, the perfon taking care to leave the room immediately, and to lock the door. In twelve hours after, the doors and windows are to be opened to let the currents of air evacuate the acid.

This is likewife employed in the rooms filled with patients, when there is reafon to fufpect them of containing animal miafmata; but in thefe cafes one third part only of the above mixture is employed, or even lefs, carrying it into every part of the room where any infection may be fuppofed to lurk. After the chambers are fufficiently full of the vapour, the apparatus is put into the neceffaries or privies, to decompofe or neutralize any bad or putrid exhalations they may contain.

Van Mons, in a report made to the Society of Medicine, at Bruffels, with refpect to the means neceffary for purifying the air in the apartments of the fick, oppofes the method of fumigation, as it diminifhes the refpirable, and adds to the unrefpirable air; in general, he found the air in fuch apartments to confift of abundance of carbonic acid, hydrogen, oxygen, and azotic gafes; fometimes a little ammoniacal gas, and a peculiar emanation, called *contagious miafma*, which appears to him to be a peculiar combination of hydrogenous carbonic acid gas, holding in folution animal fluids very little known. The hydrogen gas contains almoft always in folution pure carbon, phofphorus, &c., from which the difagreeable odour arifes. The carbonic acid would form a much more confiderable part, according to this chemift, were not this gas continually neutralized by the ammonia evolved in all difeafes where animal fubftances containing azot are decompofed. Hence the contradiction of thofe who fuppofe air to contain carbonic and ammoniacal gafes at the fame time, and the abfurdity of expofing veffels filled with quicklime in the apartments of the fick, which takes away the carbonic acid gas, and leaves the **Van Mons.**

ammoniacal. Among the beſt means of purifying infected air, this chemiſt claſſes vaporized water, which incommodes the patient leſs, and deprives air of it's putrid effluvia better than the muriatic or acetous acid, or than ſpirits, being a better ſolvent than theſe. The ſulphureous gas he thinks might decompoſe the miaſmata by giving them a portion of it's oxygen, but it leaves behind it an oxyd of ſulphur, the ſmell of which is very offenſive; hence oxygenated muriatic acid is preferable. (Annal. de Ch. vol. 29, p 99.)

With reſpect to the offenſive ſmell of different places, ſuch as privies, night-chairs, &c., an object of ſuch conſequence with reſpect to health and comfort, the moſt cheap and effectual means of deſtroying it is the following: If a certain quantity of milk of lime (water in which lime has been recently ſlacked and poured off previous to it's ſettling) be mixed with a ley of aſhes, or even ſoapy water that has been uſed for waſhing, and thrown into the ſink of a privy, or other convenience for the ſick room, it will immediately deſtroy the offenſive odour. It is obvious that a more ſimple method is, to mix a few pounds of quick lime with a ſmall quantity of wood aſhes, and a bucket of water.

The ſpirit of energy which the pneumatic method of conſidering the cauſes of peſtilence has introduced, has already created a formidable oppoſition againſt fumigations, and the deſtruction of contagion by acid vapours.

Dr. Trotter. Dr. Trotter informs us that ſeveral years ago, or in 1793, he had no faith in the fumigating proceſs, and that the acid vapours, particularly the nitrous gas, muſt be prejudicial to thoſe who are expoſed to them.

The offenſive effluvia, ſo diſagreeable to the ſmell, which the acid is to deſtroy, are, according to Dr. Trotter, ſulphurated hydrogenous gas (hepatic gas), the aërial product of fœcal matter, and ſuch as aſcends from privies; phoſ-

phorus and carbon may alfo be mixed with it; the nitrous gas certainly decompounds it, and fulphur is precipitated and the fmell vanifhes. In the fame way the nitrous acid alters the effluvia of the confluent fmall pox, when they approach beyond maturity; and alfo the offenfive matter of large floughing ulcers, which do not materially differ from the vapours arifing from the fæcal mafs. The nitrous gas, according to the fame author, decompofes the carbonic fulphurated hydrogenous gas of gunpowder fumigation, and takes away it's fmell; the oxygen of the nitrous gas combines with the hydrogen, and forms water, and the fmall portion of azot, with the fulphur and the carbon fufpended in the hydrogenous gas, is precipitated, and the fmell difappears; but Dr. Trotter thinks, that the nitrous gas, when employed againft contagious effluvia, not only adds nothing to the improvement of the qualities of the air which fupport life, but that it is introducing a fubftance that takes away part of the remaining oxygen of the atmofphere, and the different perfumes ufed as fumigations render the air more noxious, by giving out hydrogenous gas. He thinks, that although the aromatic vinegar of the Edinburgh Difpenfary, vulgarly called the vinegar of the four thieves, is of all perfumes the moft grateful, yet it's effects on the atmofphere cannot be great, and vinegar, which he fufpects gives out oxygen by evaporation, had better be ufed alone. He fuppofes, that by the fumigating procefs of Dr. Smyth, the very fubftance is introduced which ought to be avoided, and which is the vehicle, if not the noxious caufe itfelf (the fepton of Dr. Mitchill), and the experiments of Reilly, Browne, and Moffat, on board different veffels, he thinks have confuted the practice of it as a fumigation. He looks upon the noxious gafes evolved from excretions of the fick to be the vehicles of the infection; and he confiders heat as one of the moft powerful correc-

tors of contagion; it rarifies foul air, or that ſpoiled by reſpiration in crowded apartments; applied to ſubſtances imbibed with animal miaſma, it will either diſſipate it or convert it into an inert maſs, ſo as to be harmleſs; it will dry up moiſture, and above all, it is uſeful as a general ſtimulus to the body, by keeping it warm, and thus fortifying it againſt cold, which ſo evidently tends to diſpoſe it to receive infection: hence the whole preſervative means are compriſed in the removal of the ſick, cleanlineſs, fires, and ventilation. It is evident, that the opinion of Dr. Trotter is the ſame as that of Dr. Mitchill reſpecting the uſe of nitrous acid gas, who looks upon it to be the moſt prepoſterous and ill-contrived method that can enter the mind of man. Such are the principal methods that have been employed to deſtroy the putrid exhalations ariſing from the decompoſition of animal and vegetable ſubſtances, and which are called *miaſmata*.

Concluſion. *Concluſion.* There now remains to recapitulate the principal facts, and to conclude the ſubject of putrefaction.

Upon recalling to mind the principal phenomena attending ſpontaneous decompoſition, it has been ſeen, that animal matters, which are compoſed of hydrogen, carbon, oxygen, and azot, and which are often ſtill more complicated by the union of ſulphur, phoſphorus, &c., on being deprived of life, and of that conſtant action and renewal of their component parts, that appear to conſtitute it, ſoon begin to change by the more ſimple attractions taking place between each of their principles, which tend to unite by pairs. This gives riſe to binary compoſitions, ſuch as carbonic acid, nitric acid, ammonia, and carbonated hydrogenous gas, which, on being diſengaged by degrees into the atmoſphere, diminiſh in proportion the maſs of animal matters. Hence it is in conſequence of this natural decompoſition, that theſe matters are obſerved to become ſoft, to change their co-

lour, their odour, lofe their texture, form and diftribute vapours and gafes into the furrounding element, which ferve other bodies, particularly vegetables, with the neceffary materials for their formation; or, under certain circumftances, are converted into the moft deadly poifons. All the phenomena attending the putrefaction of animal fubftances are derived from the above fources. From the union of the hydrogen with the azot, arifes the formation of ammonia, which has been looked upon as the principal product of putrefaction. The combination of carbon with oxygen, explains the formation and difengagement of carbonic acid, which, on it's firft difcovery, was fuppofed to explain all the myfteries of putrefaction. The nitric acid, to the formation of which animal matters are known to contribute fo much in the manufactures of nitre, arifes from the union of the azot with the oxygen, whilft a certain quantity of hydrogen gas being difengaged, and carrying with it carbon, fulphur, and even phofphorus, is faid to create that variety of putrid odours, and that phofphorefcent light obferved in all animal fubftances during the putrefactive procefs.

Thefe volatile principles being united in pairs, and expanded through the atmofphere, there only remains a little carbon united or mixed with fome faline matter, as the phofphats of foda and lime. Sometimes it happens, that even the acid of thefe falts is decompofed, and it's radical feized by the hydrogen, fo that nothing more is found than the alkali or the earth which ferved for a bafis united to carbonic acid. Thefe refidua form a fpecies of earth, called *animal earth*, that often retains a little fulphurous and carbonated hydrogenous gas, a little oily matter, and an extract in which the vegetable creation finds abundance of materials neceffary to their increafe, which is the reafon why this animal refiduum is found to be fo beneficial as a manure.

A certain quantity of water, it has been obferved, is

neceffary for the putrid decompofition; according to Fourcroy, and fome of the French chemifts, it furnifhes the quantity of oxygen for the formation of the carbonic and nitric acids, and it contributes fingularly to the putrefactive procefs, by it's affinities. They look upon the hydrogen likewife, arifing from this decompofition of water, to contribute it's part in forming ammonia, fince it is a well known fact, that when animal matters are rendered more dilute by a large proportion of water, they afford, during their decompofition, ammonia in great abundance.

Putrefaction confifting in a fucceffion of particular attractions, and forming new combinations; it is evident, that all exterior circumftances, as temperature, a dry or moift atmofphere, the fituation of the matters, the medium in which it is carried on, &c. will caufe a variety in it's effects; hence bodies that are fufpended in the air, inhumed in the earth, or plunged in water, will undergo various modifications in their decompofition, which will likewife be diverfified by their quantity, their mafs, their connexions with neighbouring bodies, and other agents, the number and activity of which are at prefent unknown.

Hence bodies expofed to the air are foon decompofed, or if inhumed in an ifolated ftate, furrounded by a large quantity of earth, they are foon deftroyed, and their aeriform or liquid products are abforbed either by the atmofphere, or the foil around them, whilft on the contrary, when heaped together in maffes, in a deep earth that has been faturated to excefs with the effluvia and volatile products of putrefaction, it can no longer influence their decompofition by it's difpofition to receive or favour the new combinations that take place; hence they remain a long time undeftroyed; the animal matter is wholly converted into ammonia, and a concrete oil, forming a foap, as difcovered by Fourcroy in the churchyard of the Innocents.

The phenomena of decompofition of bodies plunged in water are ftill different, for in proportion as new products are formed, the water diffolves them and diftributes them into the atmofphere. A continued humidity, with a prevailing temperature of a few degrees above zero, favours the putrefaction, and the folution of thefe matters into a gafeous form; on the contrary, a dry and hot air, by evaporating the water, dries animal bodies and converts them into mummies, in the fame manner nearly as the fands of Egypt.

Although the numberlefs varieties, which the phenomena attending putrefaction prefent to the obferver, are at prefent undefcribed, and even unknown, yet the grand purpofe to which they all tend is evident; life, contrary to the chemical affinities which the component parts of bodies have towards each other, had forced them into organized combinations; but being deprived of this principle, they refume again the affinities they were deprived of, and by means of putrefaction become united into lefs complex forms. This procefs, without which both animal and vegetable bodies would remain ufelefs and inert, reduces them, therefore, to the materials of which they were compofed, in order to form a new creation, and whilft it attefts the fimplicity and grandeur of the operation, it expreffes the fecundity and power which are fo well comprehended in the philofophical expreffion of Beccher, the *circulus æterni motus*, by which he meant to pourtray the never ceafing activity of nature.

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FINIS.

INDEX.

The Roman Numerals denote the Volume, the Figures the Page.

A

G

N

R

S

W

THE END.

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0